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[656]

Competition by roads, waterways and airways.

(Continuation) (1).

Czechoslovakia and Algeria.

CZECHOSLOVAKIA.

We publish below two notes from the Czechoslovakian Ministry of Railways about the « Measures taken in order to fight road motor competition », and the « Part played by the Czechoslovakian State Railways in the field of motor transport ».

In that country, road transport is regulated by the law of the 23rd December, 1932. Without going into the details of the clauses of this law, we will merely say that, generally speaking, all public motor transport must receive authorisation, both in the case of passenger and goods transport, and regular or occasional services. Motor traffic which is not of a public nature remains unrestricted, however. Exceptions are allowed in the case of firms transporting their staff, their own goods, etc.

The State Railways and the Post Office Administration are allowed to organise public transport services without obtaining an authorisation.

Authorisations are granted by the Administration after agreement with the railway services, area railway managements or the Ministry of Railways. When the need for a regular service is recognised, the law gives the railway the priority to organise such a service.

It will be seen that the law assigns to the railway a very important part in the regulations governing motor transport. No regular transport service can be set up without the consent of the railway. As for irregular goods transport, this can only be carried out within limits, which to a great extent are decided by the railways also.

We may add that the law lays down,

(1) Cf. *Bulletin of the Railway Congress Association*, May to December 1934, and January 1935.

in particular, that the *passenger* transport charges should be given in the application for authorisation, and these rates cannot be modified without the consent of the authorities; in the case of *goods* transport, full liberty is allowed to the carriers as regards the rates.

Measures taken to fight motor competition.

a) *Passenger traffic.*

On the 1st January, 1934, new rates came into force for passengers, luggage, and express parcels traffic, in accordance with the experience acquired while the previous rates were in force, between the 1st October, 1928, and the 31st December, 1933; moreover the new rates were greatly influenced by the present economic depression, as well as by motor competition.

The new rates represent a general reduction in transport charges. The reductions are 6 % for short distances, and 12 % for longer journeys by local trains. The average reduction is about 9.5 % for the 3rd-class.

The ratio between the rates for the different classes have been changed : the 2nd-class fares have been raised to 1 1/3 of the 3rd-class fares, though they used to be 1 1/2; the 1st-class fare is now double the 3rd class : it used to be 2 1/2.

A new class of trains from the rating point of view, express trains, has been introduced; formerly there were only semi-express and stopping trains; the fares on the semi-express trains were based on those for the local trains plus a variable supplement according to distance and class. The supplement for the semi-express trains is approximately half that for the express trains.

Such reductions and other facilities which proved successful in increasing the passenger traffic have been maintained and even extended.

The minimum rates and the minimum number of passengers for special trains and for collective journeys by regular trains have been lowered. Circular tickets with a reduction of from 20 to 30, and 40 %, according to the distance, have been introduced.

Mention must also be made of the new « travel cards » for 4 or 12 return journeys, which give the passenger the right to travel with half-rate tickets after paying double or four times the price of an ordinary return ticket. The reduction in this instance is 25 % or 33 %, according to the case.

Special rates for journeys between stations where motor competition is particularly severe have been maintained or newly introduced. These rates have been found to attract passengers. Passengers have returned to the railway to such an extent that the reductions have been made good, or have even led to an increase in the receipts.

b) *Goods traffic.*

The Czechoslovakian State Railways have continued to study the acceleration of goods transport, in view of the extent of motor competition in this field.

Goods handed over to the railway in the afternoon are carried over the main lines by light trains during the night, so that they can be delivered in the morning of the following day at stations as far away as 150 km. (93 miles).

Long-distance parcels traffic between east and west, was further accelerated, as motor competition is frequently felt even over long distances. In addition, an important acceleration has been obtained by

the construction of a central transhipping ramp which was put into service during April 1934.

The Czechoslovakian law on motor transport, of December 1932, allows complete freedom to the goods transport undertakings in the matter of rates; the intervention of the public authorities in the drawing up of these rates proved to be ineffectual in other countries. However, the great differences in the rates, particularly in the case of parcels traffic, offered by the motor and the railway, have been a serious handicap for the latter.

This difference could not be removed so long as the cartage rates remained too high. The Czechoslovakian State Railways had cartage undertakings at their disposal in about 140 places, but their activities left much to be desired from the point of view of the charges and also frequently from the point of view of speed.

Seeing that the basis on which the rates for delivery or collection are calculated varied in each place, it was difficult to draw up a rate for door to door transport.

During 1932, the Czechoslovakian State Railways decided to operate their own motor lorries to lower the unduly high cartage rates charged by private firms. This step proved efficacious; negociations were started with consigning agents who for the most part had long been responsible for the cartage services. The result was that the consigning agents decided to organise themselves as a co-operative society in which the railways would share. The members of this co-operative society undertook not to use motor transport outside the towns, and to carry out a propaganda compaign on behalf of railway transport among their customers, to organise grouped consignments of parcels between towns where competition is the most severe, and above all to lower the cartage rates. The railway, in return, undertook to discontinue its own cartage services, and in the case of grouped consignments to grant such reduced rates that, thanks to the reduced cartage rates, it will be possible to offer the public door to door transport at rates equal or lower than those offered by the competing motor services.

This co-operative society was formed in February 1934 under the name « Spedra », and now includes 314 of the largest consigning firms over the whole of Czechoslovakia. From the 1st January, 1935, a general reduction has come into force and the cartage rates been made uniform. At the same date grouped consignment services of the « Spedra » startted operations in some 120 cases.

In the case of consignments by complete wagon loads, the Czechoslovakian Railways continue to make agreements with different industrial firms, in order to limit motor transport.

Certain very important special rates have been granted without any financial sacrifice on the part of the railway, by a clause in the agreement, according to which firms profiting by the special rates undertake to make use of motor transport to a very limited extent only. Agreements of this kind have already been made with the main industries of Czechoslovakia : mines, glass works, and the porcelain, spirits and sugar industries.

The special rates for coal, for example, were completed by a clause stipulating that coal must be transported by railway to the station nearest to the place where it is to be used. The mines who wish to profit by this special rate must sign

an agreement in which they promise to sell the coal only on condition that it is transported by railway, except to places in the immediate vicinity of the mines; the agreement lays down these limits very precisely in each case : on the average transport to 30 km. (18.6 miles) from the mines is allowed. In addition, the mines promise to sell to cartage firms under the same conditions as to other customers, particularly as regards rates, hours of delivery, prohibition to exceed the useful tonnage of the vehicles, etc.

A similar agreement has been made with the sugar industry : this deals with the transport of beet, beet refuse, crude and refined sugar. In the sole case of refined sugar, the Czechoslovakian Railways granted, according to the present agreement, a reduction of from 10 to 20 % to compensate the sugar factories for the premium they have to pay, according to their agreement with the railway, to the wholesale purchasers of refined sugar. This premium, the amount of which is fixed by contract, has to compensate the consignees of goods sent by rail for the cost of cartage from the station to their premises.

Generally speaking the clause restricting the use of motor transport for carrying manufactured articles and raw materials is introduced at the present time as far as possible, in every case when the rates are modified and special reduced rates granted. In this connection, particular mention must be made of the changes in the rates for wood of all kinds, especially pit props, new special reductions for the transport of grain and flour mill products, and also the reduction recently granted to the Pilsen brewery.

Part played by the Czechoslovakian State Railways in the field of road transport.

The Czechoslovakian State Railways actually operate at the present time many motor services. Judging from the statistics published in No. 7/8 of the *U.I.C. Bulletin*, 1934, the importance of these services greatly exceeds that of those operated by other railway systems. This is due to the fact that from the 1st January, 1933, the very extensive omnibus services operated by the Czechoslovakian Post Office were amalgamated with the motor services organised by the State Railways themselves (C S D), which at that time were almost as extensive as the former. The same date marks the begining of a considerable extension of the C S D services for goods transport.

The information given below will give an approximate idea of the extent of the whole of the road services operated by the Czechoslovakian State Railways themselves :

I. — *Passenger services.*

Number of omnibus services	287
Total length of these services	7 818 km. (4 857 miles).
Distance run by the vehicles in 1933	18 964 163 km. (11 784 000 miles).
Average number of omnibuses in the year 1933	637
Number of places { seats	13 222
Number of places { standing	9 315
Number of passengers carried	15 120 017
Luggage carried (number of registered consignments)	395 489

II. — *Goods services.*

Number of routes with regular services . . .	17
Length of above services	565 km. (351 miles).
Mileage of lorries over routes with regular services and other services	2 309 981 km. (1 435 380 miles).
Number of lorries	206
Loading capacity of lorries, total	597 t. (587.5 Engl. tons).
Tonnage of goods transported by lorry . . .	375 301 t. (369 372 Engl. tons).

In addition to the lorries included in the above table, the Czechoslovakian State Railways employ about 40 vans used exclusively for the transport of mails and parcels within certain towns.

As regards the nature of the services carried out, those for passenger traffic are mostly regular services, with fixed routes and timetables.

The use of the lorries varies a good deal. The first lorries put into service by the State Railways were used to substitute road transport for railway transport in the large centres, such as Prague, where the position of the stations and the way they were interconnected made it difficult and slow to send goods by rail which arrived at one station and had to be sent on from another. At the present time, there are ten centres where the transport of small parcels between stations is carried out by means of lorries belonging to the railway. In some of these centres, these services are also used to transport luggage and express parcels.

In certain towns, four at present, where the rates charged by private cartage firms were too high, or where their services were unsatisfactory for some other reason, the Czechoslovakian State Railways have organised cartage services themselves and now collect and deliver goods carried by railway.

Wherever possible, these two services are combined to obtain better utilisation of the vehicles. This is also achieved in some cases by the railway itself carrying the fuel supplied to its staff at reduced rates.

In addition, a regular goods service by railway lorries was introduced in 12 cases where such services complete railway transport. Finally, step by step and with the necessary caution, the transport of goods traffic by railway is being replaced by road transport in lorries belonging to the railway. This substitution so far only affecting local railways has in one case alone been so complete that goods traffic on the railway in question is not accepted. This measure is being tested or investigated in the case of 30 local railway lines.

The Czechoslovakian State Railways had only organised to a relatively restricted extent their own road services to fight directly the competition from private motor transport firms. They have only done so in the case of a few omnibus services, operated by the railway in order to take the place of private services already operated over a route exactly parallel to the railway, and which were causing it serious losses. The idea behind this was to undermine the competing firm and afterwards, when it had been eliminated, to attract its former customers back to the railway. If this measure was not entirely successful, at any rate it stopped unlimited development of road competition. On the other hand, the omnibus services formerly set up by the Post Office, for their part were intended to link up places

some distance from the railway, and to give them access to stations some distance away.

Generally speaking, especially in the case of goods services, the part played by the Czechoslovakian State Railways in the field of road transport has had as its main object to complete the services offered the public by the railway and to replace these, if need be, the better to meet the requirements of its customers, thereby attaching them to the railway. By this indirect method, the Czechoslovakian State Railway Administration safeguards the interests of its lines.

* * *

ALGERIA.

Algerian Railways.

The Management of the Algerian Railways has sent us the following note on the measures taken by them to meet competition from motor services.

Passengers.

To fight competition from motor services, the Algerian Railways have put into force, as from the 1st June, 1934, new rates applying to the regional services of stations within sections corresponding more or less to the traffic districts around towns of some importance. The rates granted within each section may be combined with the usual rates over the next following section alone. The object of these rates is to avoid losing short-distance traffic in which motor competition is particularly keen.

The putting into force of these measures has had an excellent effect on the railway system as a whole. Over most of the routes a definite increase in the average number of tickets issued was noticed, together with an increase in the corresponding receipts. On the whole, the decline in the receipts has been definitely slowed down.

Goods.

Rates for grouped consignments give good results.

Regulation of transport.

The decree relating to the co-ordination of road and railway services in Algeria, based on that in force in France, was signed on the 7th August, 1934.

By an ordinance dated the 13th August, the Governor General of Algeria fixed the clauses of the statement which has to be made by firms undertaking public transport services, according to clause 6 of the said decree.

By an ordinance dated the 11th October, 1934, the Governor General of Algeria, according to clause 2 of the decree of the 7th August, 1934, drew up the list of professional transport organisations called upon to nominate the experts on the Co-ordination Commission.

Investigations are in hand to obtain co-ordination.

[656. 222.1]

Note on Train Speeds,

by Lionel WIENER,
Professor at the University of Brussels.

PART II *(Continued).* [1]

Train speeds and services in different countries.

IV. — BELGIUM.

SUMMARY.

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4. Competitive lines.
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3. West line (Ostend).
4. East line (Herbesthal).
5. North line (Holland).
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7. South-east line (Luxemburg).
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2. General.
3. Services between two towns.
4. Noteworthy runs.
5. The fastest trains.
6. The longest non-stop runs.
7. Provincial centres.
8. Conclusions.

(1) See *Bulletin of the International Railway Congress Association,* October and November 1933, pages 885 and 1027; January, May, June and July 1934, pages 63, 407, 561 and 653 respectively.

The TIMES and MILEAGES are taken from the official timetable *(Indicateur Officiel)* of the 15th May, 1934. This information has been completed by other data, some of which was been courteously supplied by the *Belgian National Railways*.

CHAPTER XX.

General.

XX-1. — **Characteristics of the Belgian railway system.** — The geographical situation of Belgium at the crossing of important international traffic currents determined the way its railway system was to be built up. Since the country mainly depends on its exchange of goods, its communications were to be designed, to a greater extent perhaps than in any other country, to assist this exchange.

Consequently all the main lines are international ones adapted to local conditions, as the population is so dense that these lines also have to serve a number of important Belgian towns. The lines from north to south (Holland-France) and east to west (Germany-England) which cross at Brussels (or at Malines) thus form the first elements of a centric system which only needs to be completed by a few diagonal lines :

To the south-west : from Brussels to Lille (and Calais),
To the south-east : from Brussels to Arlon (and Luxemburg) ;

and by a few intermediate lines in the country itself :

To the west : from Brussels to Courtrai,
To the south : from Brussels to Charleroi.

The main arteries are therefore essentially transit lines, and as such are affected by the economic conditions beyond the frontiers. For this reason, the territorial and economic issues of the war have particularly affected them.

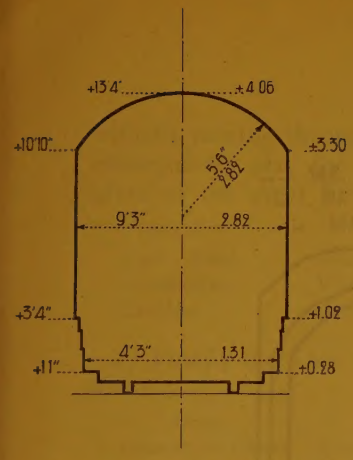
XX-2. — **The international lines can be divided into three classes :**

a) Transit lines serving Brussels (centric lines),
b) Transit lines that do not pass through Brussels,
c) Provincial lines.

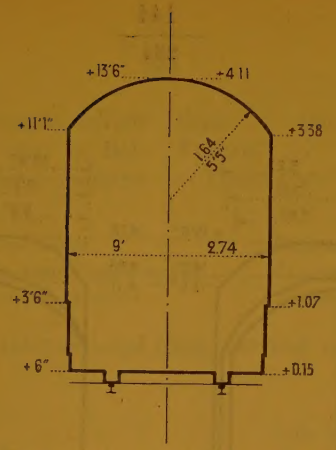
a) Differing in this respect from the French railways, the international lines which pass through Brussels are transit lines. But there are not only the lines from north to south (Holland-France) and east to west (Germany-England) ; the additional cross lines starting from Brussels have made it possible for trains starting beyond the frontier to follow, beyond Brussels, one of two main lines which in this way form *international forks;* it is interesting to compare the services over these forks with those on *national fork lines* in France or in England (cf. p. 1058/76).

Thus, trains coming from Holland via Esschen and Brussels continue towards the south (Paris) or the south-east (Luxemburg and Basle). Likewise the traffic from England via Ostend continues beyond Brussels towards the east (Cologne) or the south-east (Luxemburg or Basle), while the traffic from Cologne or Liége forks at Brussels towards the west (Ostend) or south-west (Calais).

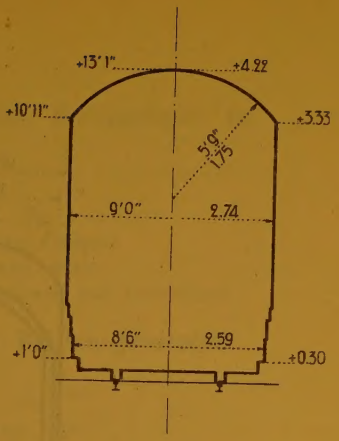
b) In addition to the international lines which pass through Brussels, there are lines linking up foreign capitals



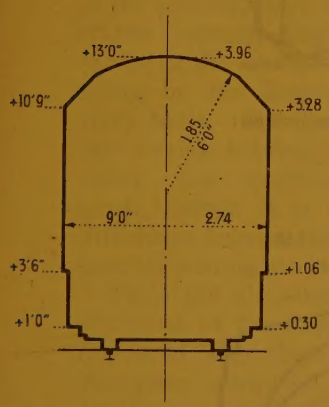
Western section (Former L. S. W.)
Southern Ry.



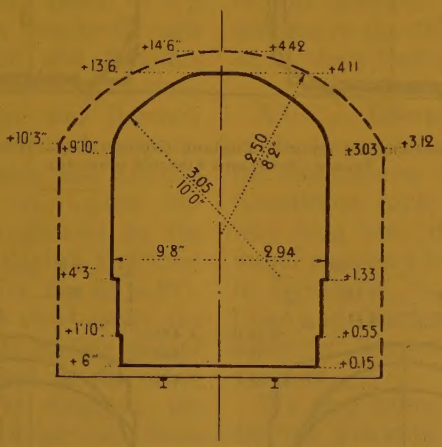
Central section (Former L. B. & S. C.)
Southern Ry.



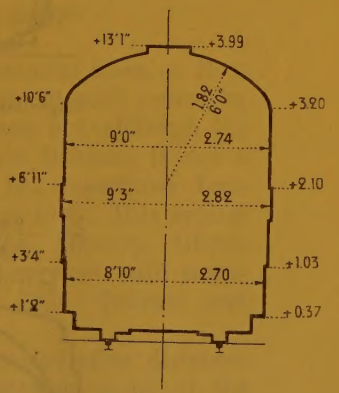
Eastern section (Former S. E. & C.)
Southern Ry.



L. M. & S. Ry.

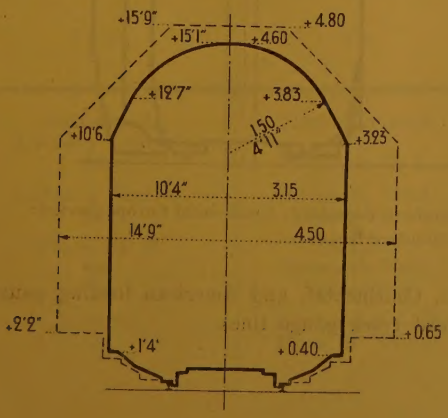


Gr. W. Ry.

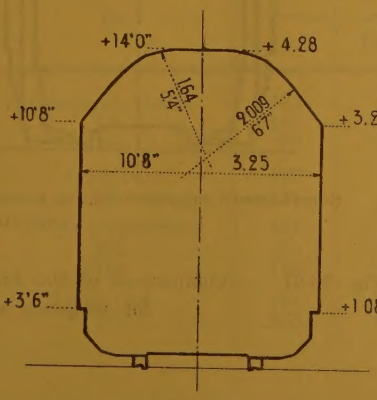


L. & N. E. Ry.

Fig. 94. — Loading gauges of the British railways.

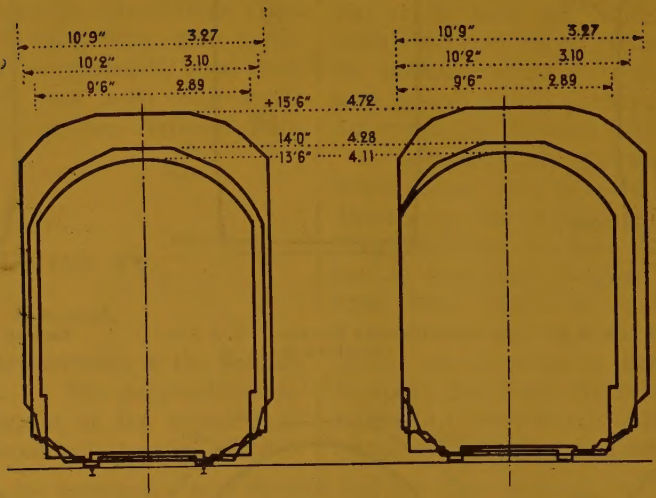


Belgian National Railways.

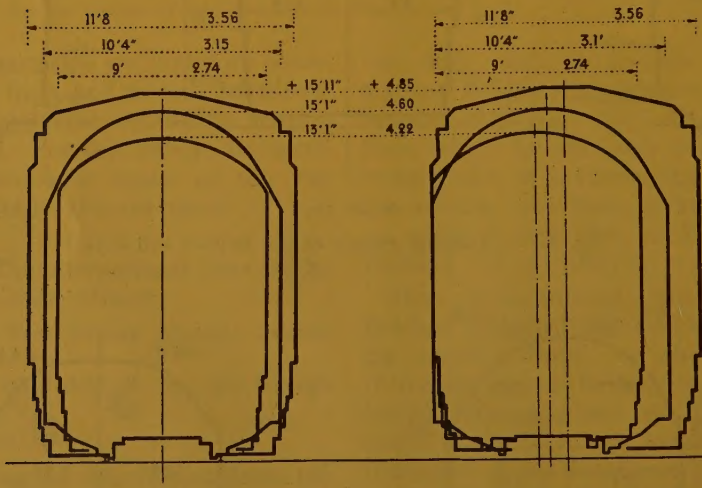


Nord Railway (Belgian Lines).

Fig. 95. — Loading gauges of the Belgian lines.



Superimposed loading gauges : England (Southern Ry., Western section) ; France (Nord) and America (Canada).



Superimposed suggested loading gauges : England (standard) Continental Europe (Berne) ; United States (Standard box car).

Fig. 96-97. — Comparison of the English, Continental, and American loading gauges for proposed standard track gauge lines.

without passing through Brussels, which consequently play the same part in Belgium as the great French cross-country lines — Calais-Lille, for example, in France.

These are :

From :	*Via :*	*To :*
Paris Nord	Jeumont and Liége	Herbesthal and Cologne
Amsterdam	Visé, Liége and Trois-Vierges	Luxemburg and Basle
London	Ostend-Antwerp-Hamont	Munchen Gladbach and Dusseldorf.

c) Finally there are some international lines serving certain Belgian provincial towns :

From :	*Via :*	*To :*
Ostend or Ghent	Mouscron	Lille and Paris Nord
Antwerp	Moll and Hamont	Munchen Gladbach and Dusseldorf.

d) Train-carrying ferry boats. — Up to the present, there has been no through traffic between England and Belgium, except in the case of goods wagons transiting by the Zeebrugge and Harwich ferry boats. But the proposed sleeping-car service between Paris and London makes this question of topical interest, though it is complicated by the difference between the English and Continental loading gauges (cf. figs 94 to 97).

Table 120 also shows very clearly the smallness of the English loading gauges compared with those used in the other European countries. In England, the loading gauges are little larger than those usually found on 3 ft. 6 in. gauge lines which we also give. We will come back to this question when considering the services in the different countries affected by these loading gauges.

XX-3. — **Interprovincial lines.** — Most of the large towns are directly served by the international lines, but, although the roundabout route via Brussels is not a very long one, it has sometimes been found necessary to avoid it. This applies in particular to the Antwerp, Ghent, Liége and Charleroi services, with extensions to Courtrai, Lille, Tournai and Verviers.

We give below comparative distances for the journeys between some of the large towns, both passing through Brussels and avoiding it :

From	Via	To	Distance	
			Km.	Miles.
Antwerp S.	Lierre-Louvain.	Charleroi Ouest.	123	76
Antwerp Central.	Do.	Do.	120	75
Do.	Brussels Q. L.	Do.	120	75
Antwerp Central.	Brussels Nord.	Courtrai.	132	82
Do.	Ghent St. P.	Do.	112	76
Ghent St. P.	Malines.	Liége Guillemins.	151	94
Do.	Brussels Nord.	Do.	154	96
Do.	Schaerbeek.	Do.	150	93
Tournai.	Brussels Q. L.-N.	Liége Gins.	194	121
Do.	Mons et Namur.	Do.	190	118

TABLE 120.

PRINCIPAL DIMENSIONS OF A FEW LOADING GAUGES.

(Rolling stock).

This table was drawn up from the data supplied by each of the Administrations concerned.

Gauge of track.	Countries.	Company or Administration.	Height of centre line.		Width.		Area.	
			Metres.	Ft.-in.	Metres.	Ft.-in.	M².	Sq. feet.
4 ft. 8 1/2 in.	Germany.	Reichsbahn	4.65	15'3"	3.15	10'4"	12.65	136.2
	Austria.	Federal (1)	4.65	15'3"	3.25	10'8"	13.00	139.9
	Belgium.	Belgian National Rys. Co.	4.60	15'1"	3.15	10'4"	12.68	136.5
	Denmark.	State	4.30	14'1"	3.15	10'4"	12.16	130.9
	France.	Alsace-Lorraine	4.65	15'3"	3.15	10'4"	13.00	139.9
		Est	4.28	14'0"	3.20	10'6"	12.54	135.0
		State (former State)	4.40	14'5"	3.20	10'6"	12.65	136.2
		Do. (Havre-Cherbourg)	4.30	14'1"	3.05	10'0"	11.65	125.4
		Do. (former Ouest)	4.28	14'0"	3.15	10'4"	11.88	127.9
		Midi	4.40	14'5"	3.21	10'6"	13.00	139.9
		Nord (France and Belg.)	4.28	14'0"	3.25	10'8"	11.10	119.5
		P. O.	4.40	14'5"	3.20	10'6"	12.42	133.7
		P. L. M.	4.30	14'1"	3.20	10'6"	12.40	133.5
		Standard (2)	4.28	14'0"	3.15	10'4"	11.75	126.5
	Italy.	State	4.30	14'1"	3.10	10'2"	12.24	131.7
	Hungary.	State	4.65	15'3"	3.25	10'8"	13.00	139.9
	Norway. Sweden.	State	4.30	14'1"	3.40	11'2"	12.85	138.3
	Holland.	Netherlands Rys.	4.57	15'0"	3.15	10'4"	12.95	139.4
	Rumania.	State	4.65	15'3"	3.15	10'4"	13.14	141 4
	Switzerland.	Federal	4.50	14'9"	3.15	10'4"	12.00	192.2
	—	Standard (3)	4.28	14'0"	3.10	10'2"	12.10	130.2
4 ft. 8 1/2 in.	England.	Southern Ry (west)	4.06	13'4"	2.82	9'3"	10.30	110 9
		Do. (east)	4.22	12'1"	2.74	9'0"	10.65	114.6
		Universal	3.86	10'8"	2.69	8'10"	9.00	96.9
4 ft. 8 1/2 in.	U. S. A.	Standard Box Car	4.72	15'6"	3.27	10'9"	14.28	153.7
	Canada.	Canadian Pacific	4.85	15'11"	3.56	11'8"	13.43	144.7
	Australia.	Commonwealth Rys.	4.42	14'6"	3.20	10'6"	13.18	141.9
	Argentina.	Standard	4.40	13'9"	3.30	10'10"	13.05	140.5
5 ft. 6 in.	Spain.	M. Z. A.	4.70	14'5"	3.60	11'9"	15.47	166.5
		Norte	4.47	14'8"	3.20	10'6"	13.45	144.8
		Andalusian	4.70	14'5"	3.50	11'6"	14.03	151.0
	India.	Madras and S. Mahratta	4.11	13'6"	3.20	10'6"	11.65	125.4
	Argentina.	Standard	4.47	14'8"	3.90	11'2"	13.88	149.4
3 ft. 6 in.	Japan.	Government Rys.	4.10	13'5"	3.10	10'2"	11.70	125.9
	Java.	State	3.70	12'2"	2.70	8'10"	9.68	104.2
	Nigeria.	Government Rys.	3.81	12'6"	2.89	9'6"	9.30	100.1
	South Africa.	South African Rys.	3.96	13'0"	3.05	10'0"	10.17	109.5
3 ft. 3 3/8 in.	Spain.	F. C. Vascongados	3.80	12'6"	2.80	9'2"	10.10	108.7
	Switzerland.	Rhaetic Ry.	3.80	12'6"	2.70	8'10"	9.54	102.7
	India.	Madras and S Mahratta	3.43	11'3"	2.59	8'6"	8.19	88.2
	Argentina.	Standard	4.07	13'4"	3.20	10'6"	11.34	122.1
2 ft. 5 1/2 in.	Jugoslavia.	State	3.64	10'11"	2.51	8'2"	8.35	89.9
1 ft. 11 5/8 in.	Argentina.	Standard	3.05	10'0"	2.40	7'10"	6.33	68.1

(1) The loading gauge of the Warsaw-Vienna line (Austria and forner Russia) was identical with this one.

(2) Convention for technical standardisation of railways, loading gauge widened by 5 cm. (2 inches).

(3) Convention for technical standardisation of railways, 1913.

On simple cross-country lines, like those from Ghent to Charleroi (with an extension to Namur) or from Liége to Jemelle, the speed is relatively low. But in some cases the provincial towns have been linked up either with Brussels or with other towns, thus forming *national fork lines* with fast trains. This applies to the following lines :

Ostend to Ghent :	Branch to Brussels . . .	117 km. (73 miles).
	or Antwerp Central . . .	136 km. (84 miles).
Verviers to Louvain :	Branch to Brussels Nord .	125 km. (78 miles).
	or Antwerp Central . . .	141 km. (88 miles).

XX-4. — **Competitive lines.** — Though there is hardly any internal railway competition in Belgium, international competition is very keen and affects in particular the English and Dutch traffic. In this connection, the great war had a disastrous effect. Ostend is no longer one of the most important stages for traffic from England to the Continent towards Alsace-Lorraine, Germany, and beyond, as it used to be, because the traffic to Alsace has been diverted to the profit of the French *Nord* and *Est* lines, and the traffic to Cologne which the ports of Ostend and Flushing competed for has also decreased proportionately. Thus a single daily express train from Ostend to Basle (with another express from Blankenberghe to Basle during the summer) has replaced the four daily 1914 expresses. On the other hand, while formerly there was no through express from Basle to Holland via Brussels, to-day there are three. When this competition is considered from the European standpoint, it will be found to affect in particular the following services :

Run.	Route via	Distance. Km.	Distance. Miles.	Time spent.
West to East.				
a) London to Brussels	Ostend.	353	219	6.53
	Calais.	393	244	6.20
b) London to Cologne	Flushing.	596	371	12.44
	Ostend.	586	364	10.18
	Calais.	618	384	10.33
c) London to Vienna (and Near East) .	Ostend-Nuremberg.	1 562	971	25.25
	Calais-Chaumont.	1 761	1 094	26.25
North to South.				
d) Amsterdam to Basle	« Rheingold ».	781	485	10.40
	« Edelweiss ».	817	508	10.40
	Maastricht-Luxemburg.	781	485	12.16

Because of the speeding up of the Ostend services, this route at the present time is the fastest way from London to all the places in the sector laying between the line served by the « Ostend-Vienna-Orient Express » to the south, and the Cologne-Berlin line to the north.

The journey via Calais usually takes

an hour longer, and by the Dutch lines it is longer still. The route via Calais is the fastest for places south of the sector considered, places such as Basle and Milan, in which case the Ostend line cannot compete. In the case of Hamburg, north of the sector, there is a difference of 21 minutes only, whether the journey is made using the French, Belgian or Dutch lines. Here is a brief summary of the best services from London to the Continent (summer 1934).

TABLE

SHOWING JOURNEY TIMES BETWEEN LONDON AND VARIOUS CONTINENTAL TOWNS, BY THE BELGIAN, FRENCH AND DUTCH COMPETING LINES.

DESTINATION.	Route followed.	Time of departure.	Time spent.	
Hamburg	Calais.	2.00 p. m.	18.33	Nord Express.
	Flushing.	10.00 a. m.	18.41	
	Ostend.	3.00 p. m.	18.54	
Berlin Fried . . .	Ostend.	3.00 p. m.	17.43	Nord Express.
	Calais.	2.00 p. m.	18.43	Do.
	Hook of Holland.	8.30 p. m.	19.51	
	Flushing.	10.00 a. m.	21.15	
Cologne	Ostend.	3.00 p. m.	10.29	Ost.-Vienna-Orient.
	Calais.	2.00 p. m.	11.44	Nord Express.
	Flushing.	10.00 a. m.	12.42	
Bucharest	Ostend.	3.00 p. m.	22.55 + 24 h.	Ost.-Vienna-Orient.
	Calais.	2.00 p. m.	23.55 + 24 h.	Orient Express.
	Ostend.	3.00 p. m.	23.55 + 24 h.	Nord Express.
Prague	Ostend.	3.00 p. m.	24.59	Ost.-Vienna-Orient.
	Calais.	2.00 p. m.	25.59	Orient Express.
Karoly Vary . . .	Ostend.	3.00 p. m.	22.10	Ostend-Vienna.
	Calais.	2.00 p. m.	23.10	Orient-Kr.-Var.
Istanbul	Ostend.	3.00 p. m.	15.32 + 48 h.	Ost.-Vienna-Orient.
	Calais.	2.00 p. m.	16.32 + 48 h.	Orient.
	Flushing.	10.00 a. m.	20.32 + 48 h.	Luxe.
Vienna	Ostend.	3.00 p. m.	25.55	Ost.-Vienna-Orient.
	Calais.	2.00 p. m.	26.25	Orient.
	Flushing.	10.00 a. m.	29.20	
Basle	Calais.	2.00 p. m.	13.28	
	Ostend.	11.00 p. m.	17.38	
Milan	Calais.	2.00 p. m.	22.40	Via Lausanne.
	Do.	11.00 a. m.	23.12	Simplon-Orient.
	Ostend.	11.00 p. m.	25.20	

XX-5. — **Terminal stations and circle railways.** — As the important Belgian services transit from one line to another, terminal stations have been systematically done away with and have only been retained in exceptional cases. Since the Verviers Ouest (1920) and Ghent Sud (1928) termini were closed, there are none in Belgium apart from those in Brussels (Nord and Midi) and Antwerp (Central and Sud) which the transit trains do not run into, Liége Longdoz, where the *Nord Belge* lines come to an end, and Nieuport, Ostend, Blankenberghe, Zeebrugge and Knocke, on the coast.

Ostend has two termini (Town and Quay) which are 4 144 m. (2.57 miles) and 3 309 m. (2.06 miles) respectively from Zeehuis junction. As these two stations are only 500 m. (0.3 mile) apart, the first is to be done away with.

XX-6. — **Political interference.** — Belgian particularism has unfortunately led to a deplorable political interference into the operation and even the construction of the railways. It was an excellent idea to remove them to some extent from electoral influences by handing over the management to a contracting company, but politics had already set their seal on certain questions.

Thus, when it became necessary to speed up the services between England and Germany, by the construction of by-pass lines between Ghent and Brussels (avoiding Alost) and between Louvain and Aix-la-Chapelle (avoiding Liége), there arose such protestations against « the diverting of the great expresses » that the scheme had to be given up, in spite of the fact that Liége would still have been on the route of the Paris and Cologne expresses. To-day the Louvain-Drieslinter section is still uncompleted though the section from Drieslinter to the frontier [72 262 m. (44.9 miles) to Montzen, and then 7 196 m. (4.47 miles) to the frontier], completed some time ago, was to a large extent built by the Germans during the war. It crosses the Meuse by a bridge 536 m. (1 758 1/2 feet) long; the rail is 75 m. (246 feet) above datum, the usual level of the water under the bridge being 51.46 m. (168 ft. 10 in.) above datum (1).

The problem of joining up the Nord and Midi stations in Brussels is a similar one, and technical considerations have only a secondary part therein; people are either for or against the junction! Consequently, though work was begun in 1909, it has been abandonned until a definite solution be arrived at.

As an example of the feeling this question can arouse, here is curious instance. When we returned to Belgium after the war, and naturally had no preconceived ideas about this junction, we were asked by an important foreign technical Journal to write an objective report on the question, together with our conclusions thereon. When the report was completed such pressure was brought to bear on the management of the publication that we were asked to agree to this issue of the paper being destroyed, although it was already printed.

(1) High-water level : 54.67 m. (179 ft. 4 in.).

CHAPTER XXI.

The main lines.

We will bring out the characteristics of these lines by dealing first of all with the lines through the capital (headings 1 and 2), and then with those starting therefrom in the following order :

3 and 4. West to east : Ostend to Brussels Nord and then on to the German frontier towards Cologne;

5 and 6. North to south : Antwerp to Brussels and then on to the French frontier, towards Paris;

7. South-east line : from Brussels to Luxemburg (towards Basle) ;

8. Charleroi line;

9. South-west line : from Brussels to Lille (towards Calais).

XXI-1. — **Trans-capital lines.** — Most international trains run through Brussels : this also applies to some of the express trains from Antwerp to the south of Belgium. Now Brussels is built in part on the side of a hill (running more or less from north to south) which separates the upper from the lower part of the town. Two termini, Brussels Nord and Brussels Midi, are situated at the bottom of the hill and about 2 500 m. (1.55 miles) apart as the crow flies, and there is a pseudo-terminus to the east, known as the Quartier-Léopold (Q. L.) station, on the top of the hill.

For a long time there has been an incomplete circle railway round the town. It links up the Midi and Nord stations (10 777 m. = 6.7 miles) passing through Brussels Ouest (West) and is used by the trains from Paris to Holland and from Calais to Cologne. These latter trains used to run into both termini until it was found more logical to run them into one of them only.

The old north-east circle line, from the Nord station to the Q. L. (6 460 m. = 4 miles) climbs the hill and, in 4 222 m. (2.62 miles), rises 40 m. (131 feet) over gradients as steep as 1 in 100 and 1 in 77, together with curves as small as 500 m. (25 chains) radius.

This railway was used almost exclusively by the Luxemburg line trains, whose suburban services as well as trains starting from Brussels, used the Quartier Léopold station as a terminal.

The tunnel and viaduct driven through the centre of the city to link up the Nord and Midi stations were intended to improve these services. In the meantime, the construction of an outer circle railway

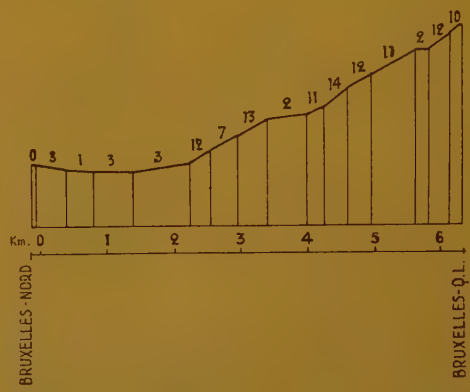


Fig. 98. — Gradient section of the line from Brussels Nord to Brussels Quartier-Léopold.

from the north to the south through the east of the town (fig. 99) changed the position. This junction leaves the Calais and Paris lines at Hal, crosses the Charleroi line at Linkebeek, and the Luxemburg line at Watermael, in order to link up with the Liége and

Fig. 99. — Brussels suburban railways.

Antwerp lines at Haeren (1). It makes it possible for goods trains to avoid the difficult section of the old north-east circle, and for the express trains to get onto the Calais, Paris and Charleroi lines by passing through the Q. L. station, which speeds up the international trains and some of the interprovincial expresses.

The different sections of the circle line are used as follows by the through trains :

TABLE 121.

UTILISATION OF THE BRUSSELS TERMINI AND CIRCLE LINES.

TRAIN			Use of the circle lines.
From	to	Via Brussels.	
Ostend Quay.	Liége Guill.	Nord.	—
Do.	Do.	Schaerbeek.	Does not enter the Nord terminus.
Do.	Luxemburg.	Nord.	North-east circle and Q. L. station.
Calais Mar.	Cologne.	Nord.	Formerly, west circle. The Pullman runs through Hal, Q. L., and the north-east circle.
Paris Nord.	Antwerp, etc.	Midi.	West circle, avoiding the Nord station.
Mons.	Antwerp Central.	Q.-L.	Hal, Q.-L., and N.-E. circle.
Charleroi.	Do.	Q.-L	Linkebeek, Q.-L. and N.-E. circle.
			Does not enter Brussels Nord.

(1) Here are some of the distances between Brussels and suburban stations.

From Brussels Midi	Kilom.	Miles.
to Hal	13.680	8.50
Jette	8.442	5.25
Laeken	7.356	4.57
Brussels Nord	10.777	6.70
Schaerbeek	9.271	5.76
From Brussels Nord		
to Laeken	2.784	1.73
Schaerbeek	2.776	1.72
Vilvorde	9.584	5.96
Brussels Q.-L.	6.458	4.01
Watermael (via Q.-L.)	10.322	6.41
Do. (via Cinquant.).	18.515	11.50

From Brussels Q.-L.	Kilom.	Miles.
to Etterbeek	2.249	1.40
Watermael	3.864	2.40
Hal (via Etterbeek)	18.617	11.57
Schaerbeek	5.035	3.13
Laeken	5.706	3.55
From Schaerbeek		
to Laeken	1.915	1.19
From Vilvorde		
to Schaerbeek	6.808	4.23
Brussels Q.-L.	11.841	7.36
Watermael (via Q.-L.)	15.705	9.76
Do. (via Cinquant.).	13.763	8.55

When the Nord-Midi Junction will be completed, the comparative distances by the old and new routes will be :

ROUTE.	By the present-day lines.		By the junction.	
	Kilom.	Miles.	Kilom.	Miles.
Calais-Brussels Nord	226	140.4	218	135.5
Paris Nord-Antwerp Central	362	225	358	222.5
Mons-Antwerp Central	114(1)	71	108	67
Charleroi-Antwerp Central	105(1)	65.2	103	64.0

Even with only one stop in Brussels, it is unlikely any time will be saved on the journey.

XXI-2. — **Lines through Antwerp.** — Apart from the lines which end at Antwerp Sud and Antwerp Central an east circle line encircles part of the town and runs north again beyond the Dam station (5 700 = 3.54 miles) which lies on the extended axis of the Brussels, Berchem and Antwerp line. If the terminal station were run through and the line extended but 1 500 m. (0.93 mile), the line to Holland could be immediately rejoined intead of encircling the whole eastern part of the town.

The fast trains between Belgium and Holland do not enter the Central station and use the circle line which has only one peculiar feature. This is that in order to serve Antwerp, these trains formerly stopped at Berchem, just before the triangle which makes it possible to run into or avoid the Central station, while they now stop at the Est station just beyond. The distances between these stations are :

Antwerp Central to Berchem . . . . . 2 048 m. (1.27 mile).
Antwerp Central to Antwerp Est . . . . . 2 187 m. (1.36 mile).
Berchem to Antwerp Est . . . . . 1 175 m. (0.73 mile).

The station on the left bank of the Scheldt (Antwerp Waes) is not linked up with the other stations by rail.

Lines through Liége. — Although the *Nord Company* has a terminal station at Longdoz, the international trains from Paris to Cologne and Liége to Maestricht only use the Guillemins station.

The distances between the various Liége stations are as follows :

Guillemins to Vivegnis 5 000 m. (3.11 miles).
Guillemins to Longdoz 3 724 m. (2.31 miles).

XXI-3. — **The line from Ostend to the German frontier** was originally laid through Malines, which was intended to be the keystone of the Belgian railway system. It has, however, since been

(2) Via Brussels Q. L.

diverted to an alternative route through Brussels. The distances by the various routes are :

Ghent St. P.-Termonde-Malines-Louvain . .	81 km. (50.3 miles).
Ghent St. P.-Brussels Nord-Louvain	84 km. (52.2 miles).
Ghent St. P.-Schaerbeek-Louvain	80 km. (49.7 miles).

Apart from its national importance, the line from Ostend to Cologne has considerable international importance; consequently there always have been Anglo-German expresses, some of which were routed via Malines right up to the war, in order to avoid congesting the capital.

When the Netherlands Railways speeded up their Flushing trains, to get hold of this traffic, before the war, a through service was introduced in Belgium, leaving Ostend at 3.25 a. m.; it reached Cologne at 9.51 a. m., having covered the 348 km. (216 miles) from Ostend at the average speed of 59.2 km. (36.8 miles) an hour. The Journey from Ostend to Verviers, the longest non-stop run in Belgium, took 3 h. 25 m. In practice, the locomotives took water at Louvain.

The line from **Brussels Nord to Ostend Town** via Alost and Schellebelle is 121 191 m. (75.31 miles) long. The branch from Ostend Zeehuis (4 144 m. = 2.57 miles from Ostend Town) to Ostend Harbour is 3 309 m. (2.06 miles) long.

The first part of this line is less easy

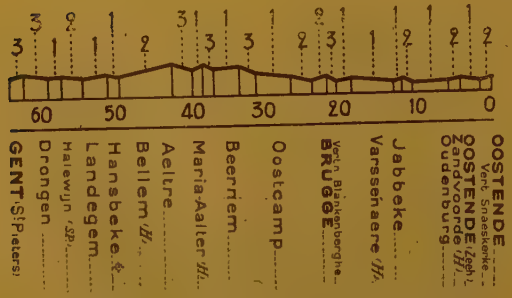


Fig. 100. — Gradient section of the Ghent and Ostend line.

than is commonly supposed. The gradient from Brussels Nord to Dilbeek (11 km. = 6.83 miles) is 5.7 mm. p. m. (1 in 175) nearly all the way, while the run down to Alost (30 km. = 18.6 miles), which follows, is 1 in 270 even reaching 1 in 227.

Beyond this, there are similar gradients as far as Ghent, after which they fall between Ghent and Bruges to 1 in 500 — a magnificent section of track including two straight stretches 23 and 10 km. (14.3 and 6.2 miles) in length connected by a curve of 1 280 m. (64 chains) radius.

As the traffic over this line was excessive at certain times of the year, and in order to shorten it, a direct line was built from Brussels Midi to Ghent St. P. (fig. 103) which crosses the old line at Denderleeuw. It is 52.14 km. (32.38 miles) long, instead of 57.61 km. (35.8 miles) by the old route, but the gradients are as steep as before. Thus, on leaving Brussels there is a gradient of 1 in 200, 9.5 km. (5.9 miles) long, followed by a similar and equally long fall. Beyond this the gradients vary between 1 in 500 to 1 in 212.

Trains starting from Brussels Nord use the new line from just before Denderleeuw (which is 23.86 km. = 14.8 miles away), while those coming from Ghent go through Denderleeuw station before running onto the new line. The distance is 52.857 km. (32.85 miles).

Before the war, work was started on

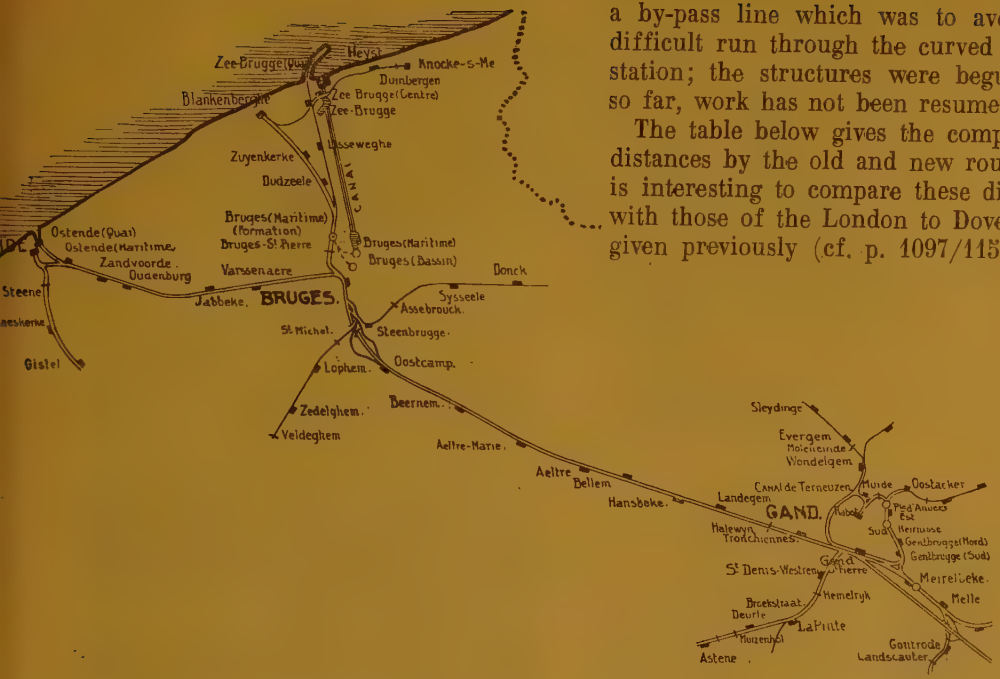


Fig. 101. — Ghent and Ostend line (smaller scale than fig. 103).

From BRUSSELS.	Line.	To					
		Denderleeuw.		Ghent.		Ostend Quay.	
		Km.	Miles.	Km.	Miles.	Km.	Miles.
Nord.	Old, via Alost'	23.862	14.8	57.420	35.6	120.166	74.7
Do.	New	23.862	14.8	54.065	33.6	116.751	72.6
Midi.	Circle and Alost . . .	29.079	18.1	62.637	38.9	125.373	77.9
Do.	New	22.257	13.8	52.400	32.5	115.046	71.5
Do.	New, direct	—	—	52.138	32.3	114.874	71.4
Schaerbeek.	New	—	—	53.420	33.1	116.166	72.2

a by-pass line which was to avoid the difficult run through the curved Bruges station; the structures were begun, but so far, work has not been resumed.

The table below gives the comparative distances by the old and new routes. It is interesting to compare these distances with those of the London to Dover lines given previously (cf. p. 1097/115).

XXI-4. — The line from **Brussels Nord to Liége and Herbesthal**, 140 km. (87 miles) long, is difficult nearly all the way, and particularly where the Meuse valley is crossed.

It rises from Schaerbeek to Louvain by continuous gradients of 1 in 200, followed by similar down gradients, and at the 28th km. (17th mile) crosses the canal over a swing bridge where the maximum

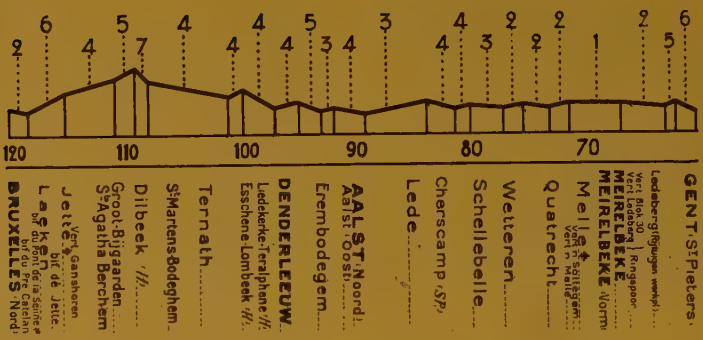


Fig. 102. — Gradient section of the old Brussels and Ghent line.

speed is reduced to 40 km. (25 miles) an hour. From Louvain to Ans, there are 65 km. (40.4 miles) of continuous up gradients reaching 1 in 222. Beyond Ans, the line has all the features of a mountain railway.

The run down from Ans to Liége where the line crosses the Meuse is very steep :

Ans is 177.06 m. (581 feet) above datum,
Haut-Pré is 121.50 m. (397 feet),
Liége Guill. is 67.46 m. (221 feet),

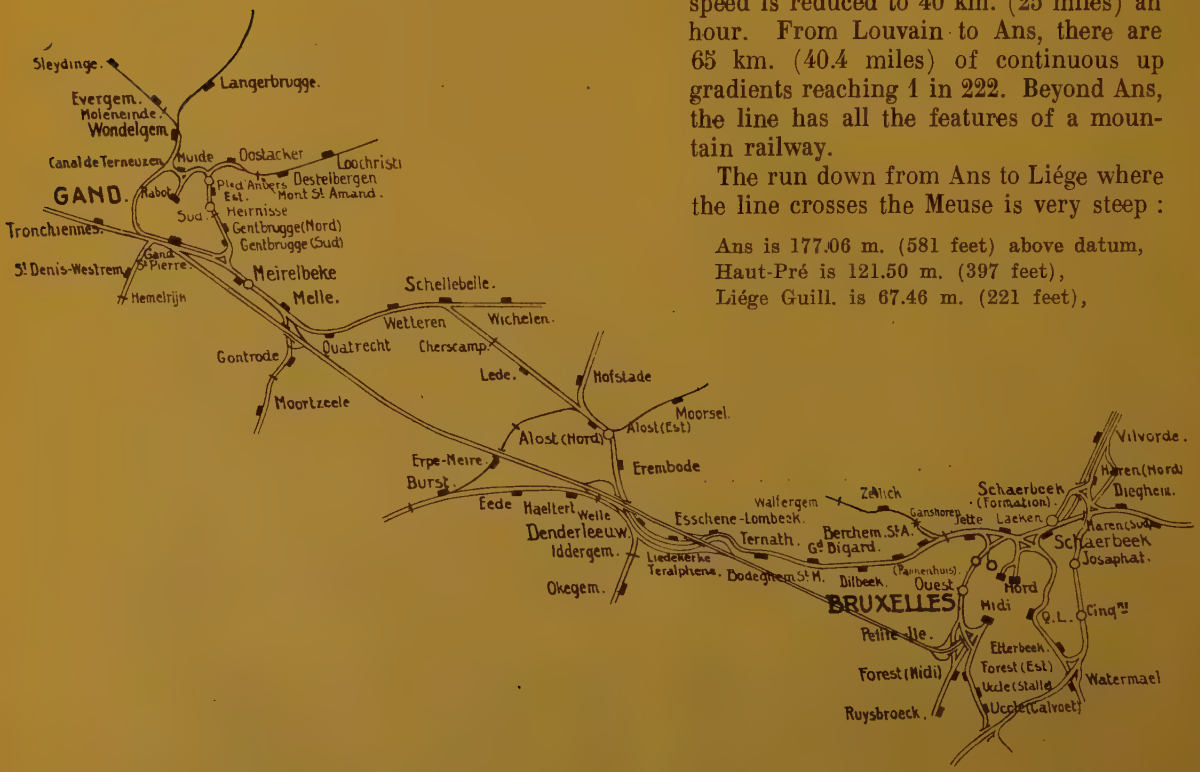


Fig. 103. — The Brussels and Ghent line.

so that there are gradients of as much as 1 in 32.

When the railway was built in 1845, cables were used. The slope was divided into two inclines 1 980 m. (1.23 miles) long with an angle of 32° between them : Each has a total rise of 55 m. (180 1/2 feet). This method remained in use until 1866 for passenger trains, and until 1871 for goods trains (1).

Each incline had a section with a very steep gradient, a section with an easier gradient, and a transition section at each end (cf. fig. 105). They caused much delay and efforts were made constantly to reduce it.

In addition to the train engine, one, two or three banking locomotives were used as pushers but not coupled up, and the train left them behind after reaching the top. A certain number of brake vans were also used on the gradient, but these were dispensed with when continuous brakes became generally used, first for passenger, and more recently for goods trains.

In 1897, a *Mallet* 0-6 + 6-0-T locomotive fitted with a new valve gear and an inadequate firebox was tried (fig. 106). The failure of this trial locomotive had unfortunate results : instead of condemning the only locomotive selected, articulated locomotives were pronounced inefficient and from that time their use proscribed on the Belgian system, although they would have proved useful, particularly in the Ardennes.

The first locomotive built by Belpaire, to run with the driver's cab in front (fig. 108), was tried in 1865 over the Brussels-Liége line. This design was again used in Italy in 1900, more recently in the United States (*Southern Pacific* R. R.), and on the *Transandine* Railway, in order to prevent the smoke affecting the visibility, especially in tunnels (2).

To keep goods trains off this difficult section, a by-pass line with easier gradients is being built, from Fexhe-le-Haut-Clocher to Kinkempois on the bank of the Meuse (fig. 107). This is 12 km. (7.5 miles) long. It is on a continuous gradient of 1 in 111 to 1 in 100, with curves of 800 m. (40 chains) and in some cases 400 m. (20 chains) radius. Its construction involved some very important structures (3).

From Liége to the German frontier, the picturesque line, 38 km. (23.6 miles) long, climbs the eastern bank of the Meuse valley with gradients of as much as 1 in 200, 1 in 166, and even 1 in 125, and 20 tunnels, of a total length of 3 713 m. (2.3 miles).

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(1) A Belgian engineer, Mr. Mauss, there made the first application of continuous traction with an engine room half way up (Haut-Pré). There were four 80-H.P. engines, one for each incline, the two others being in reserve.

The trains of 8 wagons weighed 60 tons; their speed was 20 km. (12.4 miles) an hour, and they had a special brake van with slipper brakes and one or two grips. The capacity of the inclines was six trains an hour, i.e. 8 640 tons gross per 24 hours.

The new Santos inclines were built by Messrs. Fox and Mac Arrow, on similar principles.

(2) This locomotive (fig. 108), known as the « Belgian Dragon » was built by Messrs. Ateliers de Couillet.

It was rebuilt at Malines in 1871, and converted into a locomotive with a single pair of driving wheels to haul King Leopold II 's royal train, and at the beginning of the century, the Harwich boat trains.

(3) There are four tunnels : of 720 m. (2 362 feet) (at Hollogne), of 376 m. (1 233 1/2 feet), of 132 m. (433 feet), and of 361 m. (1 184 feet) length. all on a gradient of (1 in 142 to 1 in 111). There are also two long viaducts at Horloz and at Renory, with a maximum height of 19 and 16 m. (62 and 52 1/2 feet) respectively.

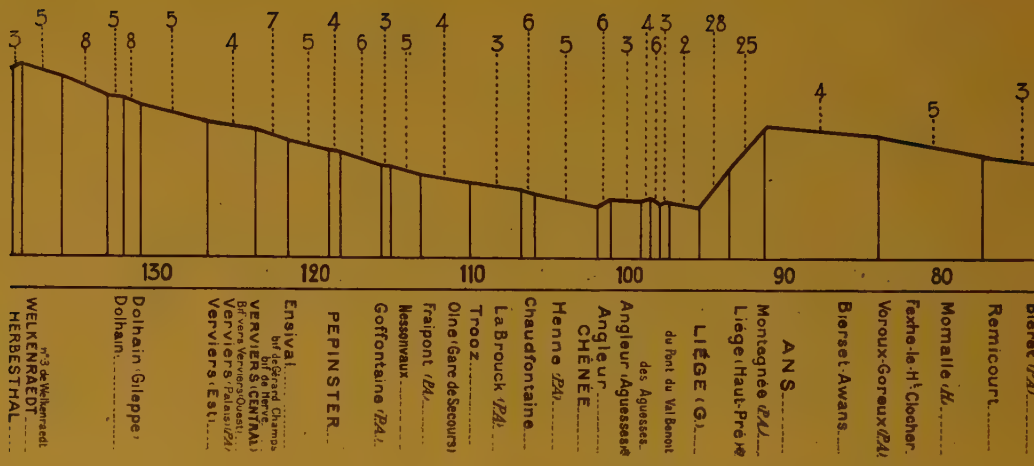


Fig. 104. — Gradient section of

XX-5. — **The line from the Dutch frontier to Brussels** is an easy one the whole way. It has been quadrupled between Brussels and Malines, and recently as far as Antwerp Central; a through line leaves it at Malines (Neckerspoel) for Antwerp Sud (fig. 109) with two intermediate stations only (1). The international express trains do not run into either of the termini at Antwerp. The distances from Brussels Nord are as follows :

From Brussels Nord to :	Kilom.	Miles
Antwerp Est (towards Holland)	42.940	26.68
Berchem (towards Holland)	41.765	25.95
Antwerp Sud	43.975	27.32
Antwerp S. Quay	44.750	27.80
Antwerp Central	43.813	27.23

The swing bridge at Malines has always been an obstacle to the speed of the trains, but when it was decided to electrify the line, electrified lines were built on their own formation and advantage was taken of this to raise them and carry them over the canal on a fixed bridge. While this was being done, the trains were sent round by Mortsel,

(1) At Waerloos and Contich.

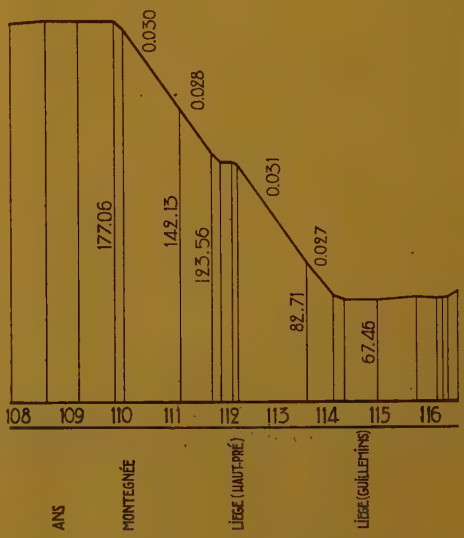
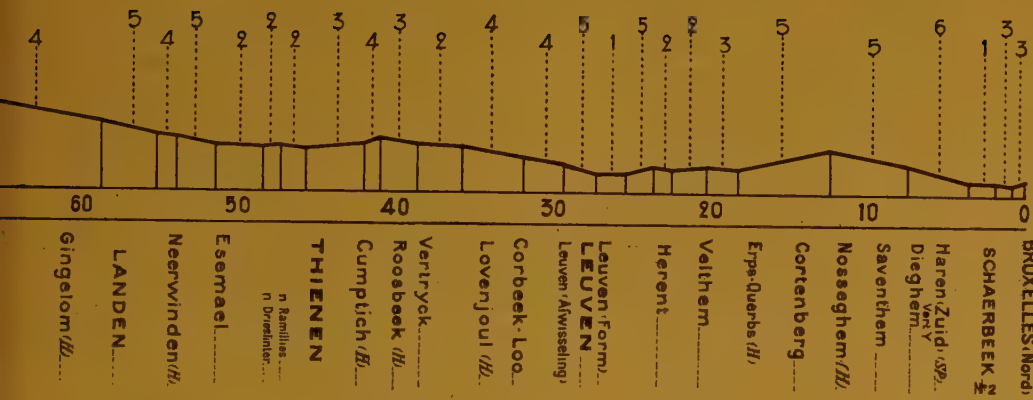


Fig. 105. — The Ans gradient (Brussels-Liége-German frontier line).



to the Brussels German frontier.

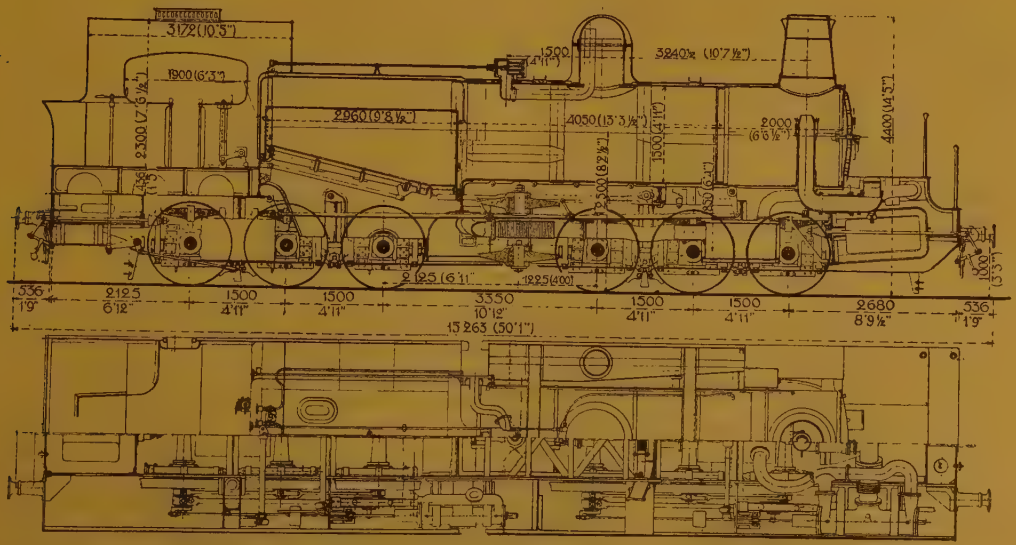


Fig. 106. — *Mallet* locomotive for working the Ans bank.

which increased the mileage by 1 400 m. (0.87 mile).

The time for the journey from Brussels Nord to Antwerp Central, which was 34 minutes before the war, was 35 minutes for a time, but since 1934, has been temporarily increased to 40 minutes owing to permanent way works.

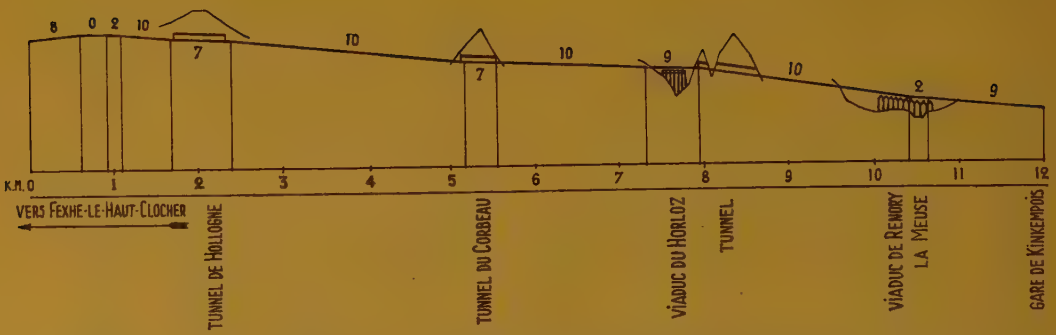


Fig. 107. — Gradient section of the line under construction between Fexhe-le-Haut-Clocher and Kinkempois.

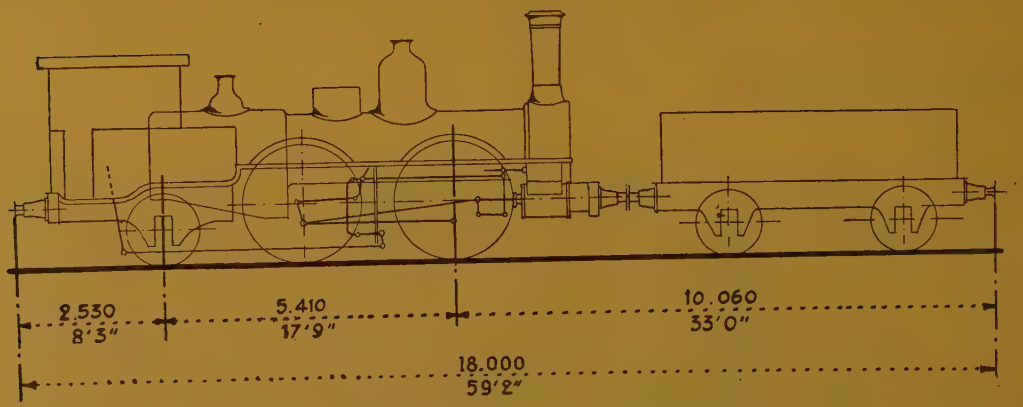


Fig. 108. — The « Belgian Dragon » for the Brussels-Liége line, 1865.

On the other hand, the international trains coming from Paris are sent on to Antwerp without passing through Brussels Nord, while those from Charleroi and Mons run directly from the Q. L. station to Schaerbeek. The distances between the various stations used by these trains are as follows :

From Brussels Midi to :	Kilom.	Miles.
Antwerp Est (to Holland)	49.430	30.71
Berchem (to Holland) . .	48.255	29.98
Antwerp Sud	54.602	33.93
Antwerp Central	50.303	31.26

From Brussels Q.-L. to :	Kilom.	Miles.
Antwerp Est (to Holland)	46.680	29.01
Antwerp Sud	51.832	32.21
Antwerp Central	47.553	29.55

XXI-6. — **The line from Brussels Midi to the French frontier** is an easy one as far as Hal (14 km. = 8.7 miles) whence it rises by a continuous gradient of 1 in 200 until the 31st km. post (19th mile) at which point it has attained an altitude of 99 m. (325 feet), a little beyond the Braine-le-Comte tunnel which is at the 27th km. post (16.8 miles). The run down onto Mons is over similar gradients

(fig. 110). Beyond this, the line belongs as far as Quévy to the *Nord Belge Company*. It rises almost continuously by gradients of 1 in 111 and even 1 in 83, as far as the frontier whence it descends towards Hautmont over gradients of 1 in 200 (fig. 111).

The 1 146 m. (0.71 mile) long Braine-le-Comte tunnel, which was built for a single track on a continuous gradient of 1 in 212 (followed by 1 in 384) was a great hindrance to operation. Consequently, the *Belgian National Railways Company* doubled it by building another track above the tunnel, for trains running in the Mons-Brussels direction. This second track leaves the first 382 m. (1 253 feet) from Braine-le-Comte station, rises by means of a gradient of 1 in 200 for 1 685 m. (5 528 feet), and descends again by a down gradient of 1 in 80 in order to join up with the first track 1 680 m. (5 512 feet) further on. The total length of the second track is therefore 3 365 m. (10 400 ft. = 2.09 miles) and it cost 9 352 000 fr. to build.

The station at Mons should also be modified — it cannot be run through at a speed exceeding 40 km. (25 miles) an hour, which is not admissible — nor is the S bend on leaving the station to the south, where the *Nord Belge* line begins.

XXI-7. — **The Luxemburg line** (fig. 112) was built by the *Société du Grand Luxembourg* to a particularly bad layout; it is a real switchback with many up and down-gradients of 1 in 62, over a series of ridges at the Soignes Forest, at Gembloux, Assesse, Haversin and Verlaine, which entail continuous gradients between Brussels and Groenendael (9 km. = 5.6 miles), between Ottignies and Lonzée (18 km. = 11.2 miles), between Jemelle and Verlaine (38 km. = 23.6 miles), etc. The first section, from Brussels to Ottignies (fig. 122) is frequently used to test new locomotives and motor vehicles.

In order to work the trains over this difficult section of track, Belpaire invented his firebox with a large grate area, capable of burning slack. He also tried on it, in addition to the usual types of locomotive, certain very unusual machines such as an express locomotive (1) with three barrels (fig. 113), a locomotive with the driver's cab half way along the barrel and a locomotive with intermediate carrying wheels (fig. 114) which

(1) The leading dimensions of this locomotive, built in 1892, were :

Cylinders	0.50 m. × 0.60 m.	(19 11/16 in. × 19 11/16 in.)
Heating surface :		
Firebox	11.3 m²	(21.6 sq. ft.)
Total	210.7 m²	(226.8 sq. ft.)
Grate area	5.0 m²	(53.8 sq. ft.)
Pressure	10 kgr./cm²	(142 lb. per sq. inch)
Number of tubes		276
Total length	9.155 m.	(30 ft.)
Total width	3.30 m.	(10 ft. 10 in.)
Total height	4.40 m.	(14 ft. 5 in.)
Wheels, diameter	2.10 m. and 1.20 m.	(6 ft. 10 21/32 in. and 3 ft. 11 1/4 in.)
Total wheelbase	6.56 m.	(21 ft. 6 1/4 in.)
Rigid wheelbase	2.20 m.	(7 ft. 3 25/64 in.)
Weight, empty	51.5 t.	(50.7 Engl. tons)
Weight in working order.	58.3 t.	(57.4 Engl. tons)
Adhesive weight	30.7 t.	(30.2 Engl. tons)

Fig. 109. — Brussels and Antwerp lin

has since been imitated in Anatolia (1). It was used for a long time on the Brussels Q. L. to Ottignies section.

In the comparative trials made with the locomotive with three barrels and the class 12 locomotives with ordinary boiler, speed was just as important a factor as the fuel consumption. The former locomotive proved to be the better one, but not sufficiently so to make up for the disadvantage of the additional maintenance costs of the special boiler (2).

(1) These Belpaire locomotives were built in 1873 by the Charles Evrard Works, of Brussels. The coupled wheels were 1.70 m. (5 ft. 7 in.) in diameter, which was large for the time; the intermediate wheels of 1.06 m. (3 ft. 6 in.) diameter had no flanges.

The last of these locomotives was scrapped in 1923.

(2) The tests were made with 150-ton trains on gradients of 1 in 200 maintaining a speed of 90 km. (56 miles) an hour over a distance of 5 km. (3.1 miles). Actually, the ordinary locomotives could easily maintain a speed of 98 km. (61 miles) an hour, and those with the special boiler 101 km. (63 miles) an hour. On 1 in 62 gradients, the speed was 64 km. (40 miles) an hour with a train of 150 tons and 50 km. (31 miles) an hour with a train of 180 tons.

During the comparative trials, the ordinary locomotive developed 1 189 H.P., and the special locomotive 1 235, reaching 1 339 H.P. during trials over a 1 in 200 gradient.

burban lines round these two towns.

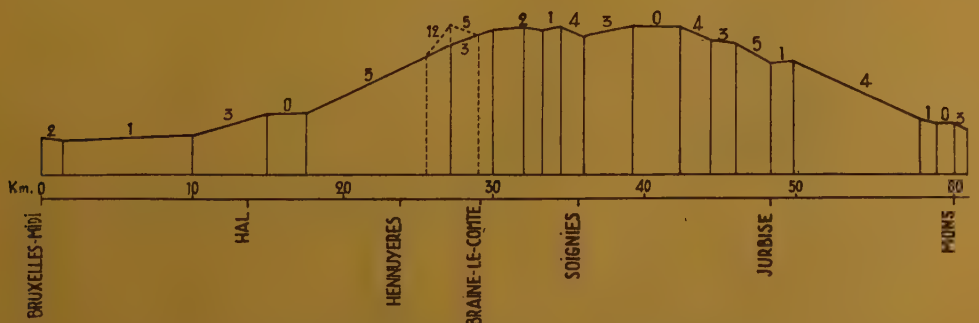


Fig. 110. — Gradient section of the Brussels Midi and Mons line.

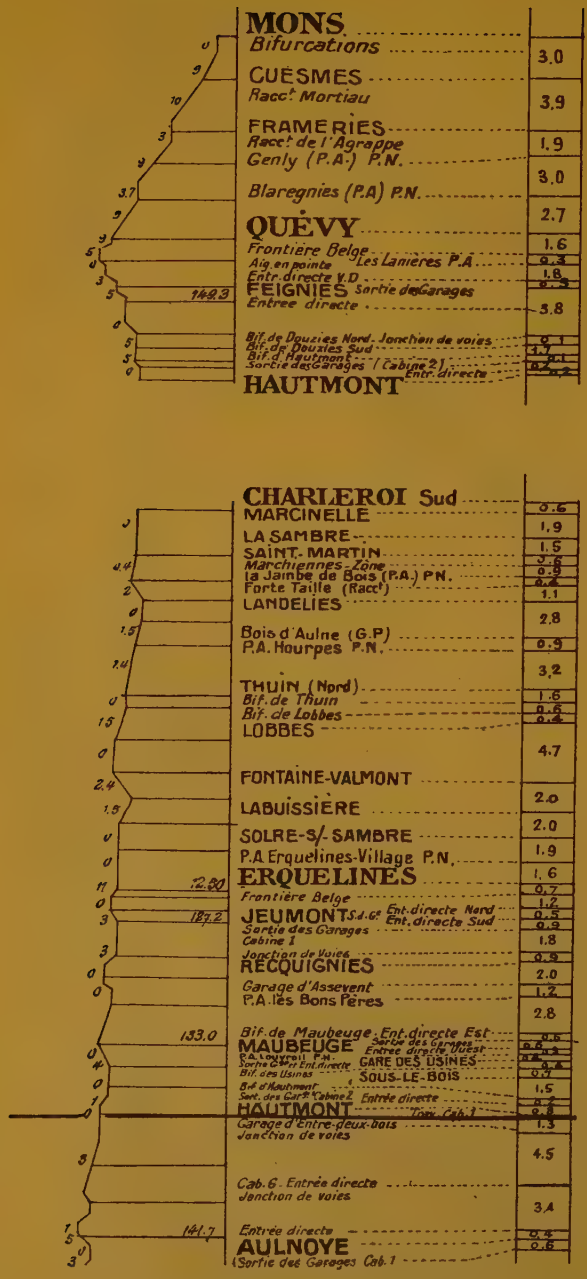


Fig. 111. — Gradient section of the Nord Belge lines.

Although a large part of the goods traffic is sent round through Athus where much work was undertaken to deal with it, the Luxembourg line was, some years ago — when the traffic was very heavy — one of those which might with advantage have been electrified. At that time the receipts would have been sufficient not only to serve for the amortisation of the financial charges of the supplementary capital involved, but also perhaps to pay off part of the capital spent on the Athus line if its traffic was to be taken away again and returned to the Luxembourg line, not forgetting the depreciation of the steam rolling stock replaced. At the present time this traffic seems to have been lost for good, so that there is little reason for electrifying the line.

XXI-8. — **The line from Brussels to Charleroi** presents every possible difficulty : gradients of as much as 1 in 77 as far as the 15th km. (9.3 miles) (Waterloo), and then less steep up to the highest point (Bois de Nivelles, 33.5 km. = 22 miles), with curves of 350 m. (17 1/2 chains) radius, and an incredible number of junctions and factory sidings. In spite of this the set trains maintain a remarkably good average speed.

The distances from Brussels are as follows :

	Km.	Miles.
From Q. L. to Charleroi Sud	58.183	36.15
From Midi to Charleroi Sud	58.018	36.05

XXI-9. — **The south-western line : Brussels-Lille-Calais,** was built as far as the frontier by a private company. It is a striking example of a line built cheaply and without due consideration. The gradients are unnecessarily heavy in order to avoid the cost of embankments, and the crossing of many stations is deplo-

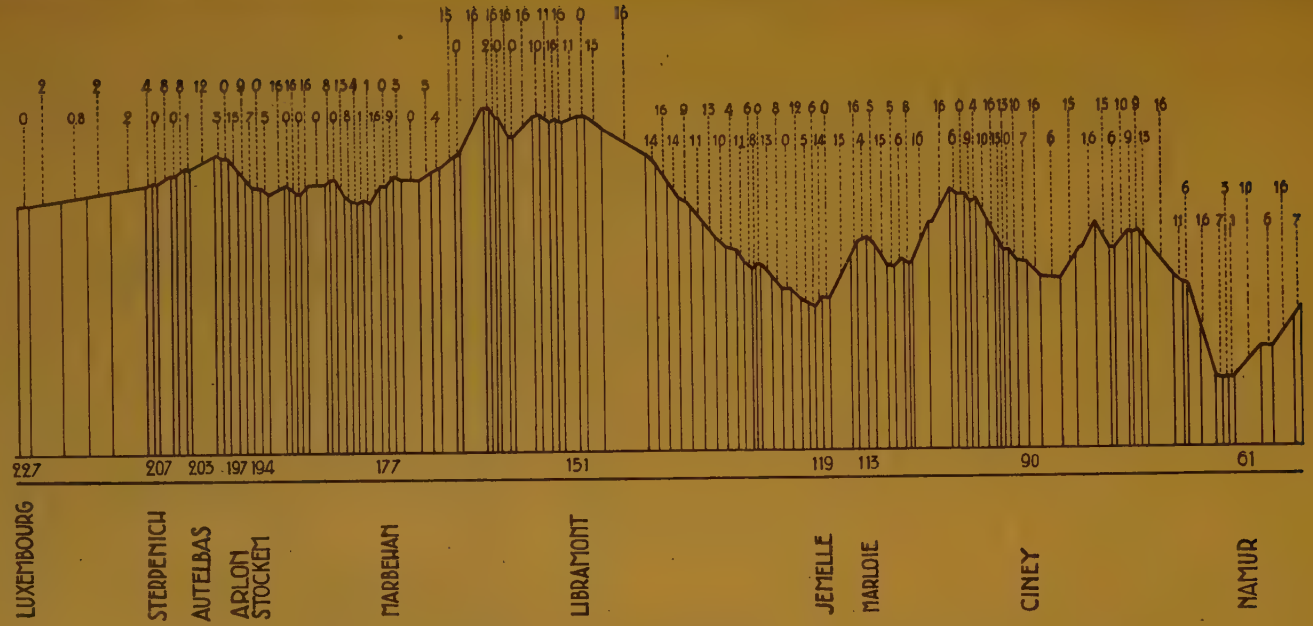


Fig. 112. — Gradient section of the Namur and Luxemburg line.

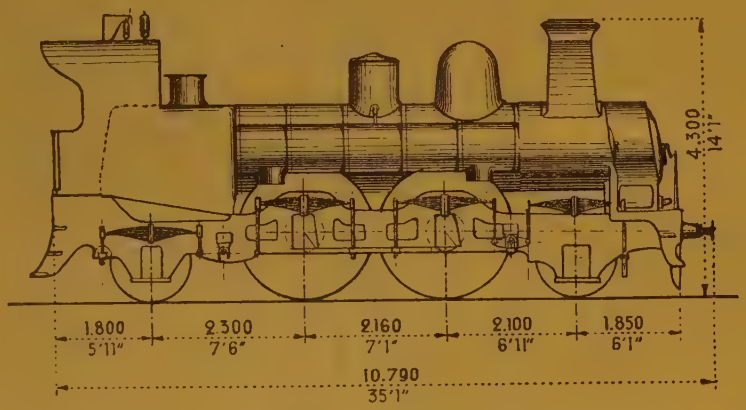


Fig. 113. — Locomotive with three barrels, for the Luxemburg line (1892).

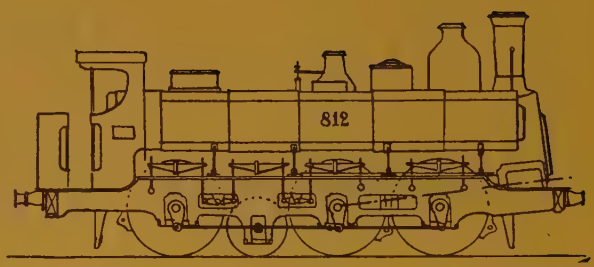


Fig. 114. — Locomotive with an intermediate pair of wheels.

rable. The layout beyond Hal has just been improved; the double bend at Ath should also be altered.

The express trains from Calais to Brussels formerly used the west circle line. Since the completion of the Hal-Watermael line, the more important one has been sent round by the east of the capital, although this journey over a heavily graded line from the Q. L. station to the Nord, is 3 km. (1.86 miles) longer (1).

CHAPTER XXII.

The train services.

As these services depend upon the economic conditions of the country, the international expresses constitute the basis of the fast services. They also serve a great number of important towns, so that the interprovincial services have been neglected until recent times. We will deal successively with :

1. The international trains.
2. The boat trains.
3. The trains to watering places.
4. The « set » trains (trains-bloc).
5. The through interprovincial trains.
6. The goods trains.

XXII-1. — **The principal international trains.** — In getting out the mileage we have not included the number of kilometres culled from a single international timetable, but from the timetables of each of the countries run through, adding up the distances obtained in this way. They frequently differ from those usually given, but we believe they are accurate. (See table 122.)

The temporary international services. — In addition to the trains to watering-places, of which we will speak elsewhere, only two seasonal international services need to be mentioned; the first is that from Amsterdam to Luxemburg (and Basle) via Maastricht and Liége, which makes greater use of the Dutch system than does the more usual route, via Brussels.

Amsterdam to Luxemburg.	Total distance.		Mileage						Time spent.
			in Holland.		in Belgium.		in Luxemburg.		
	Kilom.	Miles.	Kilom.	Miles.	Kilom.	Miles.	Kilom.	Miles	
Via Brussels	454	282	167	104	279	173	18	11	6 h. 40
Via Liége	422	262	238	148	115	71	69	43	7 h. 40

(1) Here are a few distances between stations on this line :

ROUTE.	To Hal.		To Tournai.	
	Km.	Miles.	Km.	Miles.
From Brussels Midi	13 680	8.50	84.000	52.20
Do. Nord (west circle) . . .	21.625	13.44	90.094	55.98
Do. Do. (n. e. circle) . . .	25.075	15 58	93.544	58.13
Do. Q. L. (via Hal) . . .	18.617	11.57	87.086	54.11
Blandain to Baisieux	4.707	2.92	—	—
Tournai La Madeleine (Chaix)	26.090	16.21	—	—
Tournai St. André	29.090	18 08	—	—

Table 122.

INTERNATIONAL EXPRESSES.

RUN.	Distance (1) Km.	Distance (1) Miles.	Time of departure.	Time spent.	Speed. Km/h.	Speed. Miles/h.	—
1. Via Brussels.							
London-Ostend-Brussels-Cologne	236+350	146 + 217	R 11.08 a. m.	10.18	56.8	35.3	« Pullman Exp. ».
Do. -Calais-Brussels-Cologne	167+451	104 + 280	R 4.47 a. m.	10.33	58.6	36.4	Do. + « Nord Exp. »
London-Harwich-Antwerp-Brussels Nord	361+45	224 + 28	8.30 p. m.	13.12	53.2	33.0	
Do. Do. -Zeebrugge-Brussels Nord	259+111	161 + 69	Do.	12.21	30.0	18.6	
Do. -Dover-Ostend-Brussels N.	236+117	147 + 73	3.00 p. m.	6.53	51.3	31.9	« Nord Express ».
Do. -Folkestone-Dunkirk-Brussels N.	200+192	124 + 119	R 9.04 p. m.	10.36	37.0	22.9	
Do. -Dover-Calais-Brussels N.	167+226	104 + 140	R 9.00 a. m.	6.20	62.0	38.5	« Pullman Exp. ».
Do. -Folkestone-Boulogne-Brussels N.	170+255	106 + 158	R 2.20 p. m.	8.45	48.6	30.2	
Paris Nord-Brussels Midi-Amsterdam	542	337	R 12.55 p. m.	6.50	79.5	49.4	« Etoile du Nord ».
Amsterdam-Brussels Nord-Luxemburg	454	282	7.40 a. m.	6.40	68.1	42.3	« Edelweiss ».
Do. Do. -Basle	817	508	Do.	10.40	76.6	47.6	Do.
Do. Do. -Gothard-Milan	1 189	739	R 12.20 night	20.49	56.2	34.9	Do.
Do. Do. -Loetchsberg-Milan	1 207	750	R 12.10 night	20.59	57.5	35.7	
London-Ostend-Brussels-Cologne-Berlin Schl.	236+903	147 + 561	3.00 p. m.	17.55	63.6	39.5	« Nord Express ».
Do. -Calais-Brussels-Cologne-Berlin Schl.	167+1012	104 + 629	Do.	Id.	65.8	40.9	Do.
London-Ostend-Brussels-Basle	236+706	147 + 439	R 12.20 night	16.10	58.3	36.2	
Do. Do. Do. Do. -Milan	236+1078	147 + 670	R 4.30 p. m.	24.00	54.8	34.1	
Do. Do. Do. Do. -Loetchsberg-Milan	236+1096	147 + 681	R 2.20 p. m.	26.10	50.9	31.6	
London-Ostend-Brussels-Vienna W.	236+1326	147 + 824	3.00 p m.	25.25	60.8	37.8	« Ost.-Vienna Exp. »
Do. Do. Do. Do. Budapest Ost.	236+1621	147+1007	Do.	30.35	60.2	37.4	Do.
2. Avoiding Brussels.							
Paris Nord-Liége Guill.-Cologne	492	306	R 3.04 p. m.	6.21	77.5	48.2	
Paris Nord-Lille-Ostend	342	213	R 6.48 p. m.	4.37	74.1	46.0	
Lille-Ostend	91	56.5	R 6.27 p. m.	2.13	41.7	25.9	
Amsterdam-Maestricht-Liége-Luxemburg	422	262	9.05 a. m.	7.40	55.0	34.2	
Do. Do. Do. Do. -Basle.	785	488	Do.	12.16	60.7	37.7	

(1) When two figures are given in this column, the first is the mileage from London to the Continental port, reckoned as follows :

	Km.	Miles.		Km.	Miles.		Km.	Miles.
London-Harwich	111	69	Harwich-Antwerp	250	155	Dover-Calais	42	26
Do. -Folkestone	118	73	Do. -Zeebrugge	148	92	Folkestone-Dunkirk	82	51
Do. -Dover	125	78	Dover-Ostend	111	69	Do. -Boulogne	52	32

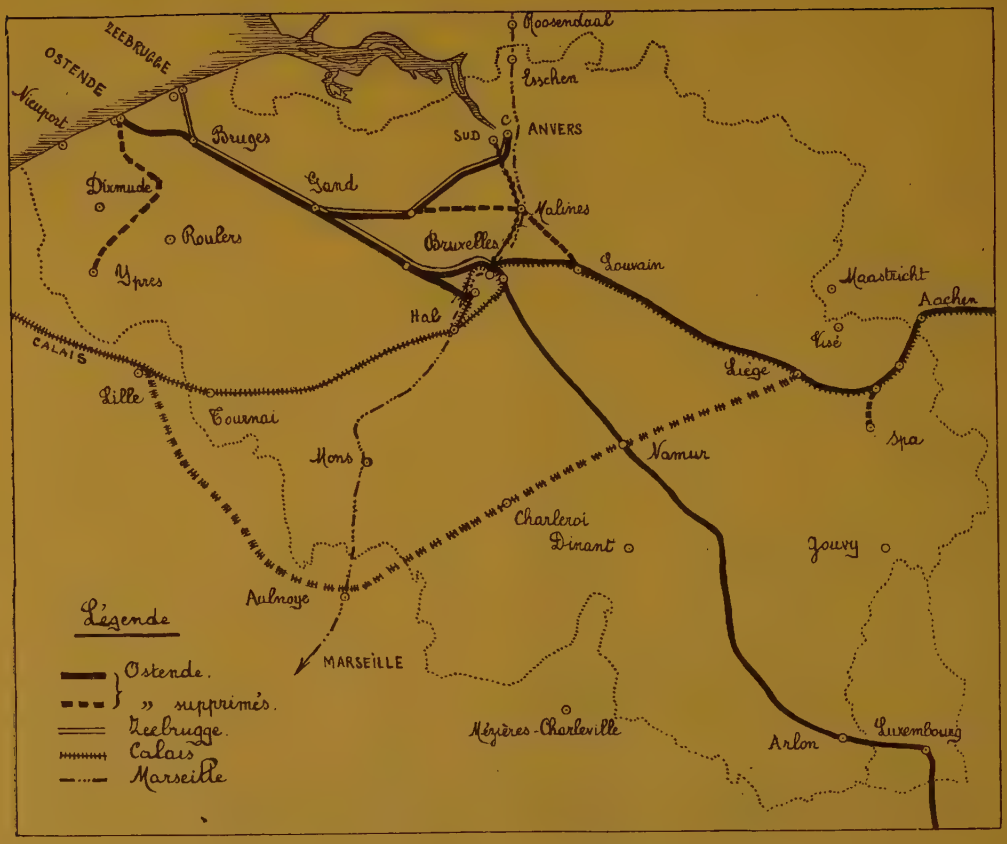


Fig. 115. — Map of Belgium showing the routes taken by the boat trains.

Note : Supprimés = obsolete.

The second is from Paris and Lille to Ostend; it is a seasonal watering-place service.

XXII-2. — **The boat trains** (fig. 115). — Ostend and Calais (or Boulogne or Dunkirk) alone are served by express trains, Antwerp and Zeebrugge to Harwich not requiring such fast services.

Before the war, there was an express service from Ostend to Antwerp, Hamont, M./Gladbach and Dusseldorf. It has been cut down since then and reduced to the part east of Antwerp, and even so runs only in summer. In the same way, the fast services from Antwerp to Cologne via Malines have been suppressed.

The « Rotterdam Lloyd Express » gives every three weeks a direct connection between The Hague, Belgium and Marseilles Arenc. It is the only through train running between Belgium and the *Paris-Lyons-Mediterranean* system.

TABLE 123.

BOAT TRAINS (Fig. 115).

Port of disembarkment.	DESTINATION OF TRAINS.	Distance.		Time of departure.	Time spent.	Speed		
		Kilom.	Miles.			Km./h.	Miles/h.	
Antwerp S. Q.	Brussels Nord	46	28.5	5.48 p. m.	0.43	64.2	39.9	
Zeebrugge Quay.	Brussels Nord-Luxemburg . .	349	217	R 3.25 p. m.	5.53	59.3	36.8	
Ostend Quay.	Ghent-Malines-Antwerp C. . .	144	89	5.01 p. m.	1.58	72.4	45.0	1 stop.
Do.	Do. -Brussels Midi	115	71	9.07 p. m.	1.18	88.4	54.9	
Do.	Do. -Brussels Nord	117	73	4.47 p. m.	1.28	79.8	49.6	2 stops.
Do.	Do.	64	40	4.24 p. m.	0.53	72.4	45.0	1 stop.
Do.	Do. -Brussels N.-Cologne . .	350	217	4.47 p. m.	5.42	61.4	38.2	
Do.	Do. -Bruss. N.-Luxem. (Basle).	355	221	6.30 p. m.	5.32	64.2	39.9	8 stops.
Do.	Do. -Malines-Liége Guill. . .	215	134	R 7.41 a. m.	2.49	76.3	47.4	4 stops.
Calais Mar.	Brussels Midi	215	134	5.55 p. m.	4.05	52.6	32.7	
Dunkirk Mar.	Brussels Midi	192	119	6.28 a. m.	4.03	47.4	29.5	
Boulogne Mar.	Brussels Midi	255	158	R 8.10 a. m.	5.27	45.4	28.2	
Do.	Brussels Nord	262	163	R 2.20 p. m.	5.04	48.4	30.1	
Marseilles Arenc.	Paris - Lyons Perrache - Bruss. M.-The Hague	1353	841	9.28 p. m.	21.40	62.4	38.8	« Rotterdam Lloyd Expr. ». Occasionally.
Do.	Paris-Lyons Brotteaux - Bruss. M.-The Hague			10.40 a. m.	21.44			

XXII-3. — **Trains to watering places.** — The watering places on the Belgian coast are spread over a distance of 53 km. (33 miles) from Knocke to Adinkerke, and they are connected with the interior of the country by lines ending at Zeebrugge, Blankenberghe, Ostend Quay (and Town), at Nieuport-Bains and at Adinkerke respectively, i.e. six lines which all go through Ghent, and the first three of which link up at Bruges and serve the coast at average intervals of 8 km. (5 miles).

As most watering places are directly linked up with Brussels (and beyond) and Antwerp, the lines have to cope with particularly heavy week-end traffic, and at such times the trains, even when not run in two parts, follow each other at intervals of 7 minutes during certain hours.

XXII-4. — **The set trains.** — In order to provide fast trains between important towns, the *State Railways* introduced, in 1908, the first set trains between Brussels and Antwerp. These were made up of two permanently coupled rakes of special stock with automatic central couplings, and carriages with bodies 2.950 m. (9 ft. 8 5/32 in.) in width, wider than the usual rolling stock. The ends of the vans were rounded off, the first rough idea of streamlining which has since been more thoroughly investigated (fig. 116). The 1st-class carriages had six-wheeled

TABLE 124.

TRAINS TO WATERING PLACES.

Train serving	DESTINATION.	Distance		Time of departure.	Time spent.	Speed.		
		Km.	Miles.			Km./h.	Miles h.	
Knocke.	Ghent St. P.-Boom-Antwerp S.	132	82	7.02 p. m.	2.36	50.8	31.6	
Do.	Do. -Brussels Midi . .	114	71	10.40 a. m.	1.51	61.6	38.3	
Do.	Bruges-Mouscron (Lille) . . .	88	55	6.36 a. m.	1.36	55.0	34.2	
Blankenberghe.	Ghent St. P.-Boom-Antwerp S.	125	78	8.36 p. m.	2.11	55.0	34.2	
Do.	Malines-Antwerp Central . .	136	85	6.55 a. m.	2.01	67.4	41.9	
Do.	Bruges-Brussels Midi	107	66	R 8.53 a. m.	1.25	75.5	46.9	Set train.
Do.	Do. -Brussels Nord-Luxemb.	335	208	R 3.25 p. m.	5.37	59.6	37.0	
Do.	Do. -Ghent-Charleroi-Namur.	201	125	5.10 p. m.	3.32	56.9	35.4	
Do.	Brussels Nord-Liége Guill. . .	209	130	1.45 p. m.	3.07	67.1	41.7	
Nieuport Bains.	Ghent St. P.-Brussels Nord. .	138	86	5.47 p. m.	2.15	61.3	38.1	
Adinkerke.	Do. -Brussels Midi . .	138	86	8.12 p. m.	1.57	70.8	44.0	2 stops.
Do.	Do. -Boom-Antwerp S.	155	96	7.30 p. m.	2.35	60.0	37.3	
Ostend.	Ghent St. P.-Brussels Nord .	117	73	4.42 p. m.	1.20	87.8	54.6	Pullman, 1 stop.
Do.	Do. -Brussels Midi . .	115	71	5.52 p. m.	1.26	80.2	49.8	
Do.	Do. -Bruss. N. - Arlon (Milan)	315	196	6.30 p. m.	4.58	63.4	39.4	
Do.	Ghent St. P.-Bruss.-Liége-Herbesthal (Cologne)	217	135	4.42 p. m.	2.48	77.5	48.2	Pullman Exp.
Do.	Ghent St. P.-Boom-Antwerp .	133	83	10.41 a. m.	2.27	54.3	33.7	
Do.	Do. -Malines-Antw. S .	144	89	8.17 a. m.	2.22	60.8	37.8	
Do.	Do. -Malines-Antw. C .	145	90	5.01 p. m.	1.58	73.2	45.5	
Spa.	Liége Guill.-Brussels Nord . .	133	83	D 9.09 p. m.	2.16	58.7	36.5	
Do.	Do. -Visé-Amsterdam . . .	295	183	5.07 p. m.	6.06	57.8	36.0	
Do.	Do. -Paris Nord	400	249	10.46 a. m.	5.54	67.8	42.1	
Do.	Do. -Louvain-Antwerp . .	149	93	5.16 p. m.	2.23	62.5	38.9	Set train.

bogies (fig. 117), a great improvement at the time (1), and under trial these trains ran between Brussels and Antwerp in 24 minutes.

(1) The leading dimensions were as follows (they are uniform for all the stock except the vans, which are six-wheeled, and the 1st-class coach bogies) :

Length of frame	21.350 m.	(70 ft. 9/16 in.).
Length of body	21.984 m.	(72 ft. 1 1/2 in.).
Exterior width of body.	2.950 m.	(9 ft. 8 5/32 in.).
Interior width of body	2.790 m.	(9 ft. 1 7/8 in.).
Height of body	4.003 m.	(13 ft. 1 19/32 in.)
Wheels, diameter	0.980 m.	(3 ft. 2 5/8 in.).
Bogie wheelbase	2.500 m.	(8 ft. 2 7/16 in.).
Bogies (1st-class carriages) . . .	3.250 m.	(10 ft. 8 in.).
Distance between bogie centres .	15.000 m.	(49 ft. 2 9/16 in.).

There were 54 seats in the 1-st class carriages, 80 in the second, and 120 in the 3rd.

Table 125.

THE SO-CALLED « TRAINS-BLOC » (SET TRAINS) (Fig. 119).

Run.	Distance. Km.	Distance. Miles.	Time of departure.	Time spent.	Speed. Km./h.	Speed. Miles/h.	
Brussels Midi-Blankenberghe	108	67	8.53 a. m.	1.25	76.2	47.3	
Brussels Midi-Ostend Quay	115	71	4.58 p. m.	1 23	83.1	51.6	2 stops.
Brussels Midi-Bruges	93	58	8.53 a. m.	1.08	82.1	51.0	
Do. -Ghent	52	32	R 7.54 a. m	0.33	94.8	58.9	
Ghent-Bruges	41	25	5.34 p. m.	0.26	94.6	58.8	
Bruges-Ostend Quay	23	14	6.04 p. m.	0.18	76.7	47.7	
Brussels Nord-Ghent	54	34	Su. 11.30 p. m.	0.38	85.3	53.0	
Brussels Nord-Antwerp Central	45(1)	28	*9.20 a. m.*	*0.35*	*77.1*	*47.9*	1933/34 winter.
	44	27	7.54 a. m.	0.40	66.0	41.0	At present.
Antwerp Central-Spa	149	93	R 5.16 p. m.	2.23	62.5	38.8	
Brussels Nord-Herbesthal	140	87	8.22 a. m.	2.02	68.8	42.8	3 stops.
Brussels Nord-Liége Guill.	100	62	R 10.52 a. m.	1.12	83.4	51.8	
Brussels Nord-Liége-Verviers	125	78	R 3.26 p. m.	1.45	72.4	45.0	2 stops (7′).
Pepinster-Liége	21	13	R 4.41 p. m.	0.20	63.0	39.1	
Ghent-Schaerbeek-Verviers	175	109	R 4.29 p. m.	2.26	71.9	44.7	3 stops.
Ghent-Schaerbeek-Liége	150	93	R 5.06 p. m.	1.49	82.6	51 3	1 stop.
Ghent-Schaerbeek	53	33	6.22 p. m.	0.35	91.5	56.9	
Schaerbeek-Liége Guill.	97	60	R 5.06 p. m.	1.09	82.9	51.5	
Brussels N.-Landen-Maeseyck.	131	81	6.10 p. m.	2.11	60.0	37.3	6 stops.
Brussels N.-Hasselt	90	56	6.10 p. m.	1.15	72.0	44.7	1 stop.
Brussels Nord-St. Trond	72	45	6.10 p. m.	0.54	80.0	49.7	
Antwerp-Louvain-Liége Guill.	116	72	R 6.07 p. m.	1.29	78.2	48.6	1933/34.
Antwerp Central-Louvain	46	29	R 6.58 p. m.	0.38	72.6	45 1	Do.
Louvain-Liége Guill.	70	43	R 8.01 a. m.	0.50	84.0	52.2	
Antwerp. C.-Bruss. Q.-L.-Charleroi	120	75	12.47 p. m.	1.30	80.0	49.7	1 stop.
Antwerp C.-Brussels Q.-L.	46(1)	28.5	12.47 p. m.	0.43	64.2	39 9	
Do.	47(1)	29.2	*6.28 p. m.*	*0.39*	*70.8*	*44 0*	1933/34.
Brussels Q.-L.-Charleroi	58	36	7.38 a. m.	0.46	75.7	47.0	
Brussels Midi-Charleroi	56	35	8.33 a. m.	0.44	76.4	47.5	
Brussels Q.-L.- Do.	58	36	7.38 a. m.	0.46	75.7	47 0	
Brussels Midi-Mons	61	38	6.44 p. m.	0.51	71.7	44.6	1 stop.
Brussels M.-Braine-le-Comte	30	18.6	R 5.22 p. m.	0.23	78.3	48.7	
Braine-le-Comte—Mons	31	19.2	8.45 a. m.	0.22	81.8	50.8	
Brussels Nord-Courtrai-Roulers	122	76	R 7.10 a. m.	1.49	60.0	37.3	
Brussels Nord-Courtrai	87	54	R 7.48 a. m.	1.11	73.5	45.7	
Courtrai-Ingelmunster	11	6.8	R 7.25 a. m.	0.11	60.0	37.3	
Iseghem-Roulers	11	6.8	R 7.10 a. m.	0.10	66.0	41.0	
Brussels Midi-Courtrai	85	53	R 5.29 p. m.	1.09	73.9	45.9	
Antwerp C.-Ghent-Mouscron (Lille).	125	78	R 4.33 p. m.	1.53	66.4	41.3	2 stops (7′).
Antwerp Central-Courtrai	112	70	R 4.54 p. m.	1.37	70.0	43.5	1 stop ((5′).
Do. -Ghent	72	45	5.29 p. m.	1.02	69.4	43.1	Decelerated 3′.
Ghent-Courtrai	42	26	R 4.54 p. m.	0.30	82.0	51.0	
Courtrai-Mouscron	13	8.0	R 4.38 p. m.	0.12	65.0	40.4	

(1) Distance increased by 1 400 m. (0.87 mile) while work is in progress.

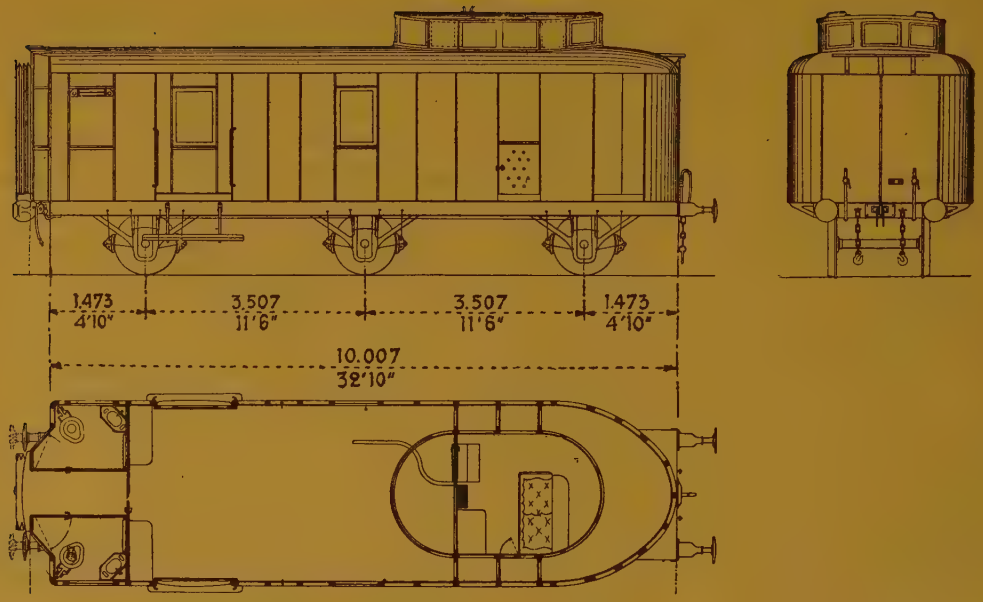


Fig. 116. — Van with rounded ends, used on the first set trains.

Since then the use of set trains has been extended; at the present time they run between the following places (fig. 119) :

Brussels and Ghent (or Ostend), Blankenberghe during the season; Liége or Herbesthal, Courtrai-Roulers; Charleroi; Mons and, recently, Hasselt and Maeseyck.

From Antwerp to Brussels and Charleroi; Ghent, Courtrai, and Mouscron (to Lille); Louvain and Liége, and, during the season, to Spa.

From Ghent St. P. to Liége and Verviers, via Schaerbeek.

These trains are made up of the ordinary stock in use and are no longer « set trains », though still known by this name, instead of being called « rapides » as in other countries. Some of the services, like those from Ostend, are noteworthy for their speed, others, like those on the Charleroi line, for their overall speed of 76 km. (47.2 miles) over so difficult a line with much traffic.

XXII-6. — **The goods trains.** — The maximum speed of the fast goods trains is limited to 70 km. (43.5 miles) an hour; their load must not exceed 72 pairs of wheels. The load of all the trains is increased by 10 % during the summer.

On the Ostend line, which is an easy one, the weight in winter is :

1 610 t. (1 584 Engl. tons) for class 38 locom.
1 430 t. (1 407 Engl. tons) for class 81 locom.

and in the case of fast trains (No. 6, from Ostend to Montzen)

625 t. (615 Engl. tons) for class 7 locomotives.

TABLE 126.

SOME OF THE THROUGH INTERPROVINCIAL TRAINS.
(Fig. 120).

RUN.	Distance		Time of departure.			Time spent.	Speed.		
	Km.	Miles.					Km./	Miles/h.	
VIA BRUSSELS.									
Ostend Quay-Bruss. Nord-Liége G. .	217	135	R	1.13	p. m.	2.40	81.4	50.6	« Pullman Exp. ».
Do. -Bruss. Nord-Arlon . .	315	196	R	5.51	a. m.	4.50	65.2	40.5	Genoa-Ostend.
Antwerp C.-Bruss. Q.-L.-Charleroi S.	104	65		12.47	p. m.	1.30	69.3	43.1	Set train.
Antwerp E.-Bruss. Midi-Mons . . .	109	68		12.25	p. m.	1.48	60.6	37.7	Amsterdam-Paris.
Do. -Bruss. N.—Q.-L.—Arlon	237	147	R	12.28	p. m.	3.51	61.1	38.0	Basle-The Hague.
Antwerp C. Do. -Mons .	113	70		7.43	p. m.	1.49	62.2	38.7	
AVOIDING BRUSSELS.									
Blankenberghe-Ghent-Boom-Antw. S.	125	78		8.36	p. m.	2.11	57.2	35.5	
Do. -Ghent-Malines Do. .	136	85		6.55	a. m.	2.01	68.0	42.3	
Do. -Ghent-Liége Guill. .	209	130		1.45	p. m.	3.07	67.1	41.7	
Ostend Quay-Ghent-Antwerp C. . .	144	89	R	8.06	a. m.	2.13	65.0	40.4	Set train.
Do. -Malines-Liége Guill. .	215	134	R	7.41	a. m.	3.20	64.5	40.1	
Do. -Schaerbeek Do. .	150	93		6.22	p. m.	1.48	83.3	51.8	Set train.
Do. -Mouscron (Lille) . .	73	45		6.48	p. m.	1.02	70.6	43.9	To Paris.
Ghent St. P.-Charleroi Sud	108	67		7.35	a. m.	2.00	54.0	33.6	
Antwerp C.-Ghent-Mouscron (Lille) .	135	84	R	7.30	a. m.	1.53	71.7	44.6	Set train.
Do. -Malines-Ghent-Adinkerke .	167	104		7.44	a. m.	2.33	65.5	40.7	
Do. -Louvain-Liége Guill. . .	116	72		4.42	p. m.	1.32	75.7	46.9	
Antwerp S.-Louvain-Charleroi Ouest.	112	70	R	5.44	p. m.	2.08	52.5	32.6	
Liége Guill.-Gouvy (Luxemburg) .	83	52		1.17	p. m.	1.33	53.6	33.3	From Amsterdam.
Do. -Namur-Tournai (Lille) .	190	118		7.32	a. m.	2.50	66.1	41.1	
Liége-Namur	60	37		Do.		0.42	85.4	53.1	
Namur-Charleroi	37	23	R	7.49	a. m.	0.30	74.0	46.0	
Charleroi — Haine-Saint-Pierre .	23	14		8.49	a. m.	0.25	55.2	34.3	
Haine-Saint-Pierre — Mons . .	21	13		9.14	a. m.	0.20	63.0	39.1	
Mons — Saint-Ghislain	10	6		9.35	a. m.	0.09	66.7	41.4	
Saint-Ghislain — Tournai . . .	39	24		9.44	a. m.	0.38	61.5	38.2	

Fig. 119. — Map of Belgium showing the lines run over by the « set trains ».

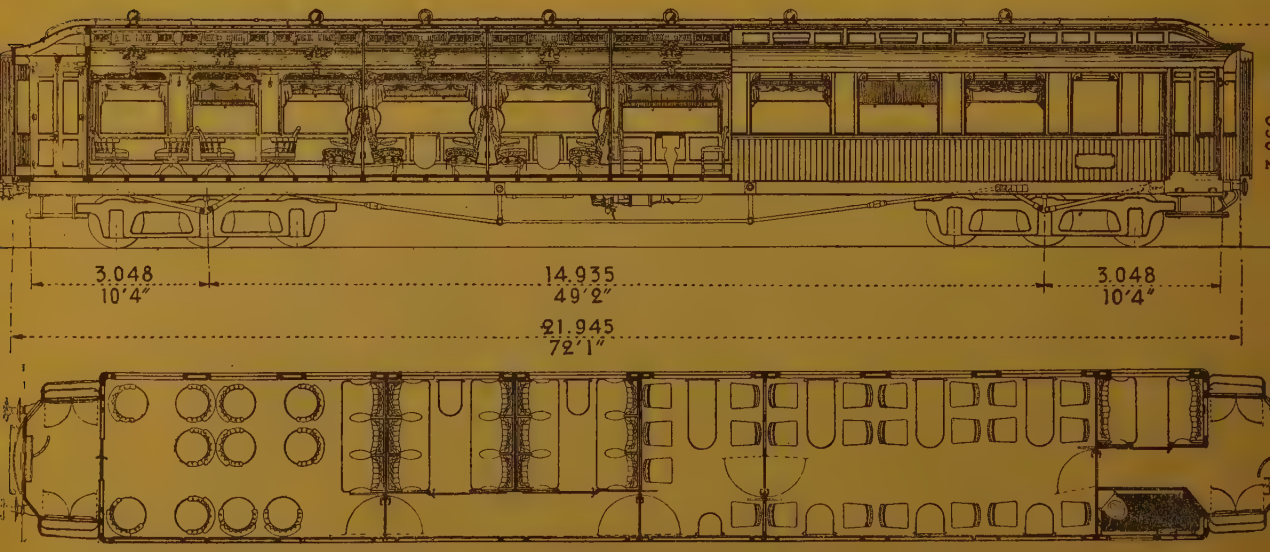


Fig. 117. — First-class carriage with six-wheeled bogies used on the first set trains.

Fig. 120. — Map showing the main interprovincial services.

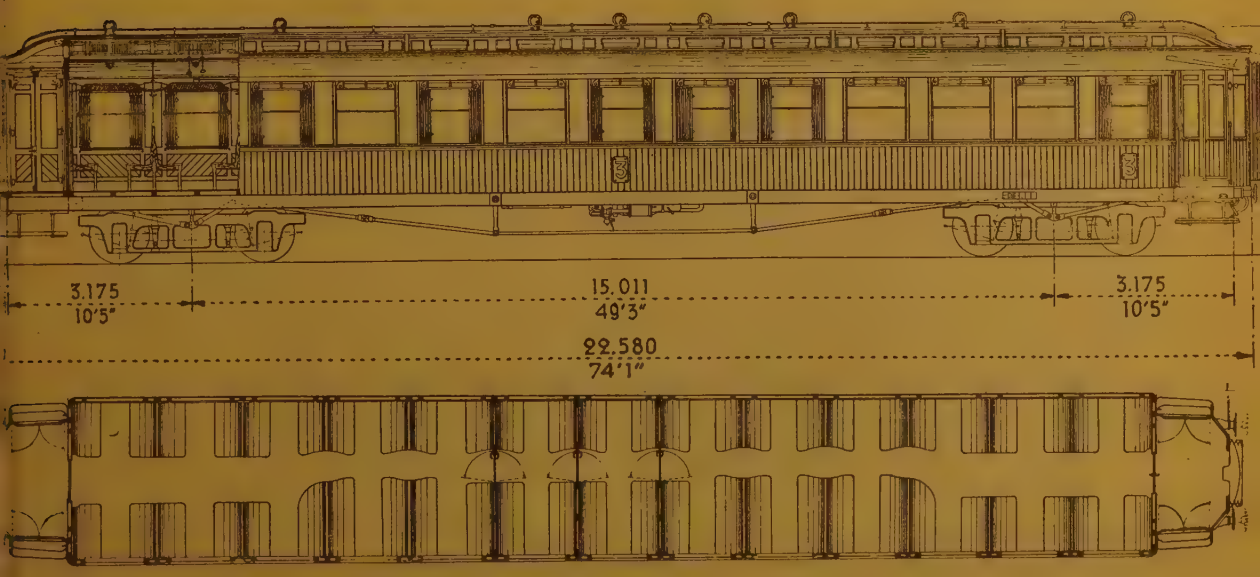


Fig. 118. — Third-class carriage used on the first set trains.

The following are a few examples of runs by these trains :

TABLE 124.

EXAMPLES OF GOODS TRAINS.

Train No.	RUN.	Distance		Time of departure.	Time spent.	Speed		
		Kilom.	Miles.			Km./h.	Miles/h.	
6167	Ans-Louvain . . .	64	40	9.22 p. m.	1.35	40.5	25.2	
9526	Gendron-Latour . .	118	73	6.00 p. m.	3.57	30.0	18.6	One 10′ stop.
G. V. 6	Ostend-Montzen . .	251	156	6.15 p. m.	7.53	31.8	19.8	625 t. (615 Engl. t.) class. 7 loco.
7412	Montzen-Zeebrugge	249	155	2.22 a. m.	6.13	40.1	24.9	30 wag. classes 38/64 locos.

The first two runs are made without stopping for coal or water. The trains from Antwerp to Montzen take water at Hasselt. The trains from Zeebrugge to Montzen change engines at Louvain.

In view of the difficult technical conditions, traction over the Luxemburg line is obviously the more interesting. In 1930, one locomotive could not haul more than 440-ton loads. Hauled by class 36 locomotives, with a class 37 pilot (present 31 class), the load reached 1 250 t. (1 230 Engl. tons) on the Arlon-Schaerbeek run, and 1 150 t. (1 130 Engl. tons) in the opposite direction.

At the present time, thanks to the general use of the continuous brake, these loads have been altered as follows tons) in the opposite direction.

Schaerbeek-Stockem .	720 t. (708 Engl. tons).	One class 35 or improved class 36 (1).
Do. .	630 t. (620 —	One standard class 36.
Stockem-Schaerbeek .	770 t. (757 —	One class 35, standard or improved.
Do. .	680 t. (669 —	One standard class 36.
Do. .	550 t. (541 —	One class 31, 38 or 81.

In addition, since July 1932, the speed of some of these trains has been increased to 50 km. (31.1 miles) an hour on the gradients, which has saved 21 minutes in one direction, and 39 in the other.

The trains from Liége to Latour, which run over the Luxemburg line between Marloie and the junction, block 73, are composed of special wagons and are made up to the following maximum weights :

Marloie-Libramont.	1 400 t. (1 378 Engl. t.).	One improved class 36 + 1 standard class 36.
Libramont-Marloie.	1 438 t. (1 415 —	Do. do. + do.
Do.	1 720 t. (1 693 —	Do. do. + 2 do.

(1) The weights of the different types of locomotives (with their tenders), used on this line, are as follows :

35 . . . 108 400 + 54 800 = 163 200 kgr. (106.7 + 53.9 = 160.6 Engl. tons).
36 . . . 107 200 + 54 000 = 161 200 kgr. (105.5 + 53.1 = 158.6 —
81 . . . . 67 800 + 44 500 = 112 300 kgr. (66.7 + 43.8 = 110.5 —
31 . . . 89 700 + 53 620 = 143 320 kgr. (88.3 + 52.8 = 141.1 —
38 . . . 84 900 + 53 620 = 138 520 kgr. (83.6 + 52.7 = 136.3 —

Part of the traffic on the Athus-Meuse line has been diverted; in former times trains of 1 438 tons were hauled between Latour and Houyet by two class 81 locomotives and by three between Meix and Saint-Vincent. At the present time, the 1 000-ton trains are hauled by one ordinary class 36 locomotive, with a pilot between Meix and Saint-Vincent.

There are very few regular *international goods trains*. We may mention, however, the weekly banana train from Rotterdam to Switzerland, which, between Esschen and Stockem (No. 6820), weighs 1 100 t. (1 082 Engl. tons). The locomotive is changed at Schaerbeek.

In the other direction, the Stockem-Schaerbeek run (198 km. = 123 miles) takes 7 hours with stops for water at Jemelle and Jambes-Secours (1).

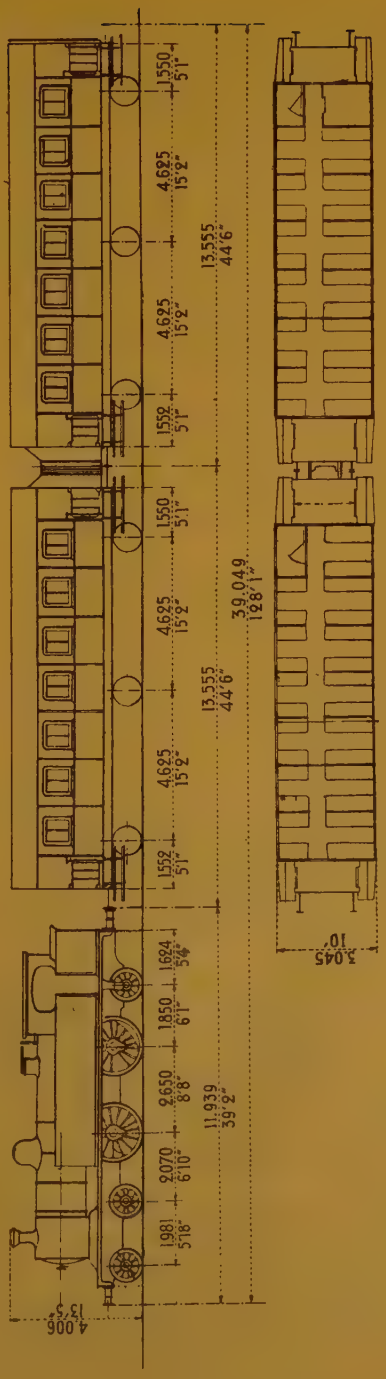


Fig. 121. — A light train (T train).

CHAPTER XXIII.

Local or country services.

XXIII-1. — **General.** — In order to fight motor competition, many local trains have been introduced, running very fast, and in spite of many stops, the journey takes less time than by the heavy trains they replace. Although in principle such services should be worked by rail motor coaches, for the time being appropriated existing stock is used. This consists of small 64-t. (63 Engl. tons)

(1) This train is hauled by an improved class 36 locomotive when the load does not exceed 770 t. (758 Engl. tons).

Below we give the weight of the other types of locomotives (and their tenders) :

Class 7 . . 83 496 + 53 600 = 137 096 kgr.
(82.2 + 52.7 = 134.9 Engl. t.).

Class 64 . . 75 280 + 50 770 = 126 050 kgr.
(74.1 + 50.0 = 124.1 Engl. t.).

tank engines hauling two coaches weighing 46 t. (45.3 Engl. tons) with vestibules and with 16 + 92 seats and standing room for 48 (fig. 121).

These light trains, officially known as T or TT trains, have been nickmaned « trottinettes » (« scooters ») by the public, and have given excellent results.

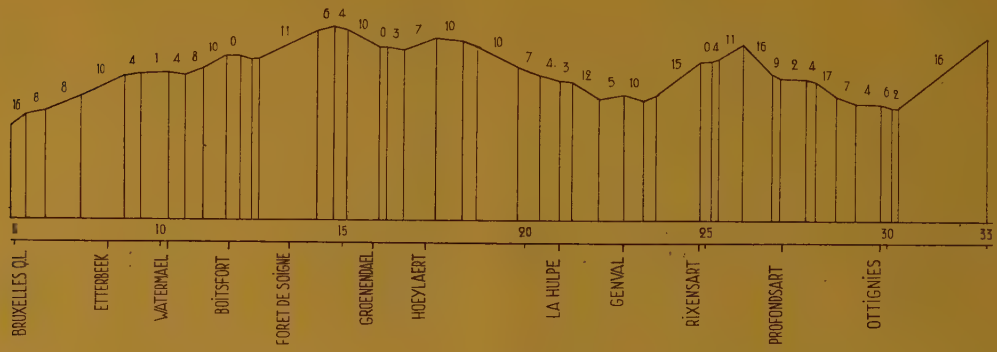


Fig. 122. — Gradient section of the Brussels-Ottignies line.

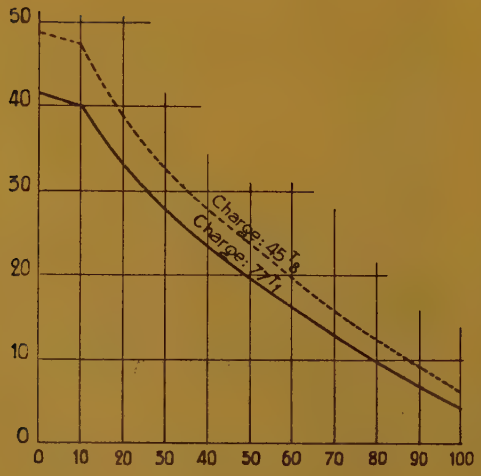


Fig. 123.

Following a completely different policy from that of the *Nord Railway*, France, which has suppressed a number of stopping places, the Belgian Railways have on the contrary multiplied them by adding supplementary halts between existing stations, and this has enabled them to attract back to the railway many passengers who had gone over to the road. In spite of these numerous stops, 15 seconds being allowed for each, the average speed of these little trains is high. A maximum speed of 100 km. (62 miles) an hour has been authorised at certain points.

During the trials, which took place on the 12th August 1933 on the difficult line from Brussels Q. L. to Ottignies (cf. fig. 122), the average indicated H.P. was 501 on the outward journey, and 530 on the return journey. On the 9th August, with 3 coaches weighing 77 tons, the indicated H.P. was practically equal to the maximum, i.e. 550 and 582 H.P. (fig. 123).

Rail motor coaches of various designs are often tried over this same section of line.

TABLE 128.

A FEW T AND TT (SO-CALLED « TROTTINETTES ») TRAIN SERVICES.

For comparison purposes, we have given in italics some of the services worked by other trains.

RUN.	Distance		Time of departure.	Time spent.	Speed.		Number of stops.
	Km.	Miles.			Km./h.	Miles/h.	
Louvain-Aerschot	16	9.9	T 2.20 a. m.	0.19	50.4	31.3	4
Hasselt-Liége Vivegnis	51	32	T 11.21 a. m.	0.49	62.4	38.8	2
Tongres-Liége Vivegnis	24	15	T 12.22 p. m.	0.30	48.0	29.8	9
Malines-Louvain	25	15.5	T 7.18 p. m.	0 33	45.5	28.3	10
Antwerp-Lierre-Aerschot	43	27	T 6.05 a. m.	0.59	43.7	27.2	20
Termonde-Malines	26	16	T 6.22 p. m.	0.37	42 2	26.2	13
Brussels N.-Opwyck-Termonde	32	20	TT 8.40 a. m.	0.44	42.3	26.3	13
			8.21 a. m.	*0.37*	*51.9*	*32.3*	*2*
Brussels-Alost-Termonde	43	27	R *9.05 a. m.*	*0.45*	*57.3*	*35.6*	*1*
Ottignies-Brussels Q.-L.	24	15	T 5.18 a. m.	0.33	43.7	27 2	11
			TT 6.50 a. m.	0.33	43.7	27.2	11
Renaix-Tournai	30	19	TT 8.20 a. m.	0.47	38.3	23.8	12
Saint-Nicolas—Ghent	42	26	TT 1.23 p. m.	1.08	37.1	23.1	16
Courtrai-Renaix	28	17	TT 9.26 p. m.	0.45	36.3	22.6	13
Denderleeuw-Mons	60	37	T 11.35 a. m.	1 43	34.9	21.7	24

XXIII-2. — **Rail motor coaches.** — Belgium was one of the first countries to make use of rail motor coaches, which in those days were called « steam coaches » and were first thought of by that inspired engineer, Belpaire.

The first Belpaire vehicles were put into service in 1877; improved designs were introduced in 1888 and 1889 (cf. fig. 124).

These were eight-wheeled vehicles with an engine unit in front, and 1st, 2nd and

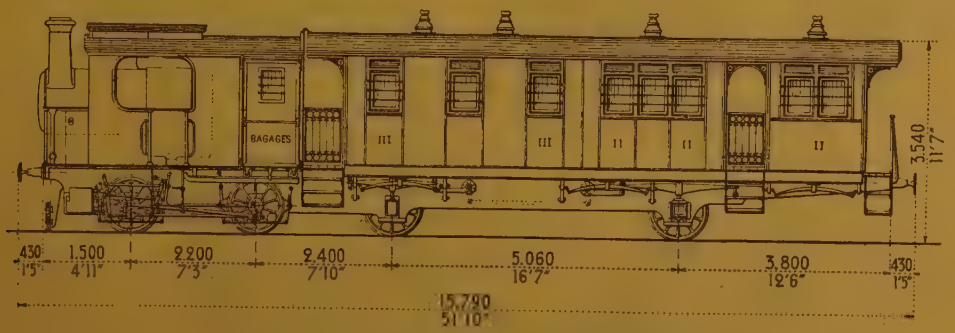


Fig. 124. — An early Belpaire steam coach.

TABLE 129.

LEADING DIMENSIONS OF THE STEAM RAIL MOTOR COACHES (Figs. 124 to 126).

BUILDER OR TYPE.	Belpaire. coach.	Belpaire. coach.	Metropolitan Sentinel.	Birmingham Yorkshire.
Date put into service	1877	1889	1930	1933
Engine.			six of	three of
Cylinders	0.17 m. × 0. 32 m. (6 11/16 in. × 12 9/16 in.)	0.20 m. × 0.35 m. (7 7/8 in. × 13 3/4 in.)	0.152 m.×0.179 m. (6 in. × 7 in.)	0.146 m.×0.203 m. (5 3/4 in. × 8 in.)
Heating surface :				
Firebox	...	4.13 m² (44.4 sq. ft.)	3.60 m² (38.7 sq. ft.)	2.38 m² (25.6 sq. ft.)
Tubes	22.62 m² (243.5 sq. ft.)	26.43 m² (284.5 sq. ft.)	3.25 m² (35.0 sq. ft.)	11.90 m² (128 sq. ft.)
Grate area	0.98 m² (10.5 sq. ft.)	1.08 m² (11.6 sq. ft.)	0.465 m² (5.0 sq. ft.)	0.622 m² (6.7 sq. ft.)
Boiler pressure	10 kgr./cm² (142 lb. per sq. inch)	12 kgr./cm² (170.7 lb. per sq. inch)	21 kgr./cm² (300 lb. per sq. inch)	19.35 kgr./cm² (275 lb. per sq. inch)
Water capacity	1 100 l. (290 Br. gall.)	1 800 l. (475 Br. gall.)	2 000 l. (528 Br. gall.)	2 120 l. (560 Br. gall.)
Coal capacity	700 kgr. (1 540 lb.)	500 kgr. (1 100 lb.)	1 700 kgr. (3 750 lb.)	2 000 kgr. (4 400 lb.)
Vehicle.				
Length, overall	12.67 m. (41 ft. 7 in.)	15.79 m. (51 ft. 10 in.)	19.10 m. (62 ft. 8 in.)	19.811 m. (65 ft.)
Width, overall	2.98 m. (9 ft. 9 5/16 in.)	3.13 m. (10 ft. 3 15/64 in.)	2.743 m. (9 ft.)	3.029 m. (9 ft. 11 9/32 in.)
Height, overall	4.30 m. (14 ft. 1 5/16 in.)	...	3.765 m. (12 ft. 4 1/4 in.)	4.095 m. (13 ft. 5 15/64 in.)
Places { seated	53	53	62	82 + 4
Places { standing	8	8	40	50
Wheels, diameter	0.98 m. (3 ft. 2 19/32 in.)	1.08 m. (3 ft. 6 1/2 in.)	0.94 m. (3 ft. 1 in.)	1.054 m. (3 ft. 5 1/2 in.)
— number	6	8	8	8
Wheel base, total	6.80 m. (22 ft. 8 in.)	9.66 m. (31 ft. 8 in.)	14.427 m. (47 ft. 4 in.)	17.475 m. (57 ft. 4 in.)
— rigid	1.20 m. (3 ft. 8 15/64 in.)	2.20 m. (7 ft. 2 5/8 in.)	...	...
— coupled	2.20 m. (7 ft. 2 5/8 in.)	2.20 m. (7 ft. 2 5/8 in.)	2.133 m.-1.981 m. (7 ft.-6 ft. 6 in.)	2.362 m.-2.134 m. (7 ft. 9 in.-7 ft.)
Between bogie centres	...	...	12.370 m. (40 ft. 7 in.)	15.227 m. (49 ft. 11 1/2 in.)
Weight, empty	...	24 t. (23.6 Engl. tons)	30.05 t. (29.5 Engl. tons)	39.32 t. (38.6 Engl. tons)
— in working order	21 t. (20.7 Engl. tons)	33 t. (32.5 Engl. tons)	34.154 t. (33.5 Engl. tons)	43.69 t. (43.0 Engl. tons)
— loaded	...	...	39.154 t. (38.5 Engl. tons)	50.69 t. (50 Engl. tons)
— adhesive	11 t. (10.8 Engl. tons)	17 t. (16.7 Engl. tons)	13.095 t. (13.0 Engl. tons)	34.0 t. (33.46 Engl .tons)

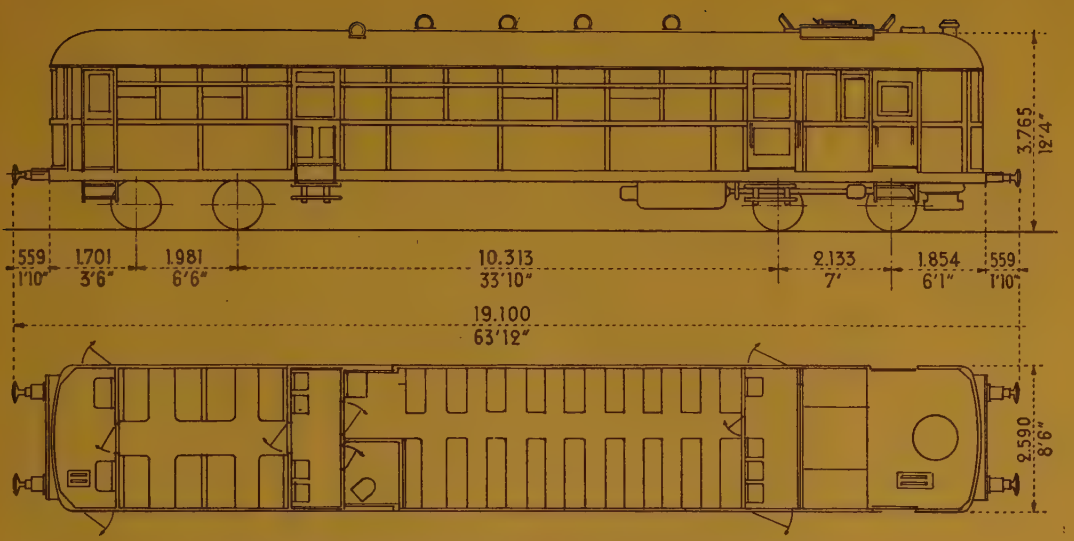


Fig. 125. — Sentinel-Cammell steam rail motor coach.

3rd-class compartments. They were soon followed by locomotive-brakes for « tramway trains ».

Steam rail motor coaches are once more being used on the Belgian Railways, who now own Sentinel vehicles (fig. 125) and a Birmingham one (fig. 126) used for suburban services at Liége (Esneux, Visé and Verviers), where they run an average daily mileage of 250. For the leading dimensions of these vehicles and those of their predecessors, see table 129.

It is difficult to explain the great popularity of the road motor bus, which is certainly due to some extent to psychological reasons. Now, the railway companies have had the happy idea of painting their rail motor coaches with bright colours outside and their success is to some measure due to this. Think of the usual dirty, dusty railway carriages, with their massive and heavy appearance, and compare this with the graceful lines and attractive colours of the rail motor coaches, and you will start wondering whether such factors have been sufficiently taken into account.

This is not the place to consider how far rail motor coaches, of fast or slower types, will replace or complete certain classes of passenger and even parcels and goods services. But it cannot be denied that they will eventually play a very important part in railway transport, the more so as they do not require the considerable capital expenditure necessary for electrification, and because, even when the trials do not give the hoped-for results, the operator has not to carry a heavy extra capital expenditure as in electrification, and so has not to meet its charges.

The Belgian Railways have also in service a number of diesel rail motor coaches, with mechanical transmission for small or average power units (fig. 129), and with electric transmission in other cases.

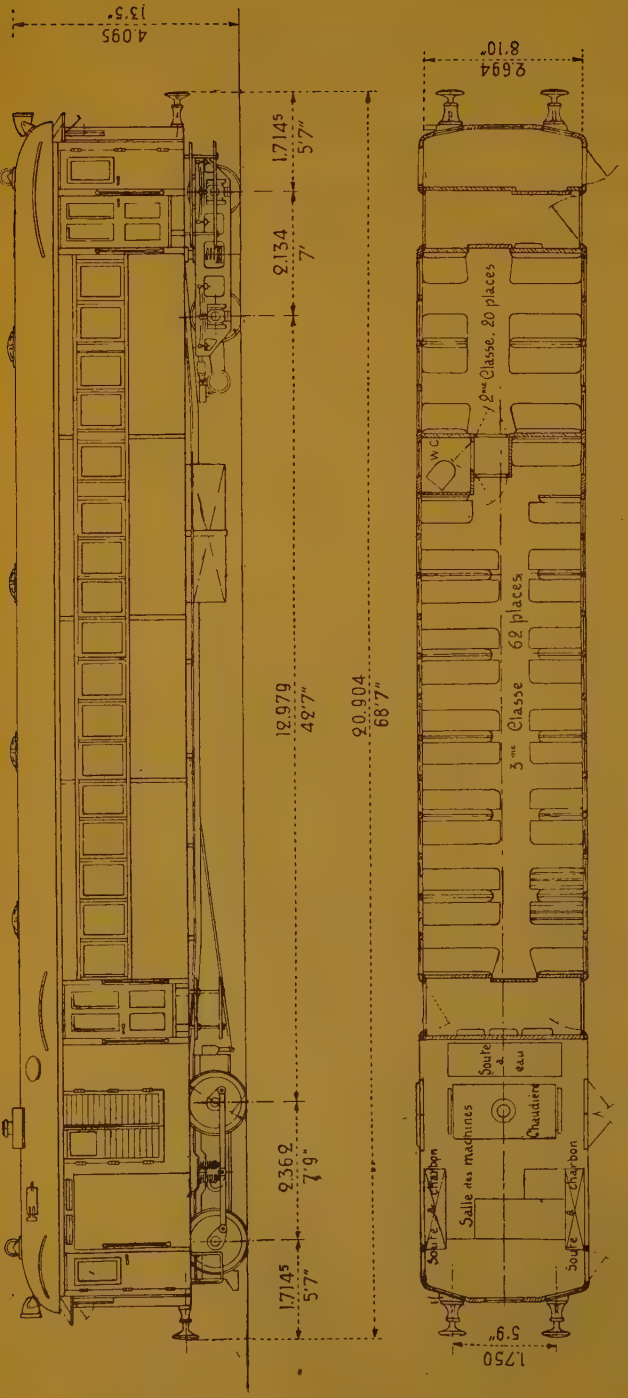


Fig. 126. — Birmingham steam rail motor coach.

Fast rail motor trains (1). — A double-unit Maybach vehicle is used on the Brussels-Midi to Ghent line, where it makes five daily trips in both directions. The other trains booked at the same speed are worked by steam locomotives.

Its acceleration is from 9 to 10 cm. (0.29 to 0.32 ft.) per sec. per sec. (2).

Inversely, the brake tests gave the following results, up to the complete stop :

From 80 km. (50 miles) an hour on the level 21 sec., i.e. 105 cm. (3.44 ft.) per sec. per sec.

From 98 km. (60.9 miles) an hour on the level 24 sec., i.e. 113 cm. (3.71 ft.) per sec. per sec.

From 134 km. (83.2 miles) an hour on a down gradient of 1 in 133, 37 sec., i.e. 100 cm. (3.28 ft.) per sec. per sec.

In this latter case the stopping distance was 700 m. (765 yards).

Since 15th October 1934, the journey takes 32 minutes, which corresponds to an average speed of 97.8 km. (60.8 miles) an hour, taking into account the run out of

(1) Cf. chapter dealing with the fast Dutch rail motor coaches.

(2) The results of tests carried out from this point of view are as follows :

Speed. Km./h. (Miles/h.)	Time (seconds).		
10 (6.2)	20	30	40
20 (12.4)	35	44	58
30 (18.6)	45	54	68
40 (25.0)	60	62	75
50 (31.0)	72	75	88
60 (37.3)	86	90	102
70 (43.5)	105	108	122
80 (50.0)	130	132	145
90 (56.0)	160	160	175
100 (62.0)	195	190	210
110 (68.3)	250	245	270
120 (75.0)	345	332	...

Fig. 127. — Map showing the lines worked by rail motor coaches.

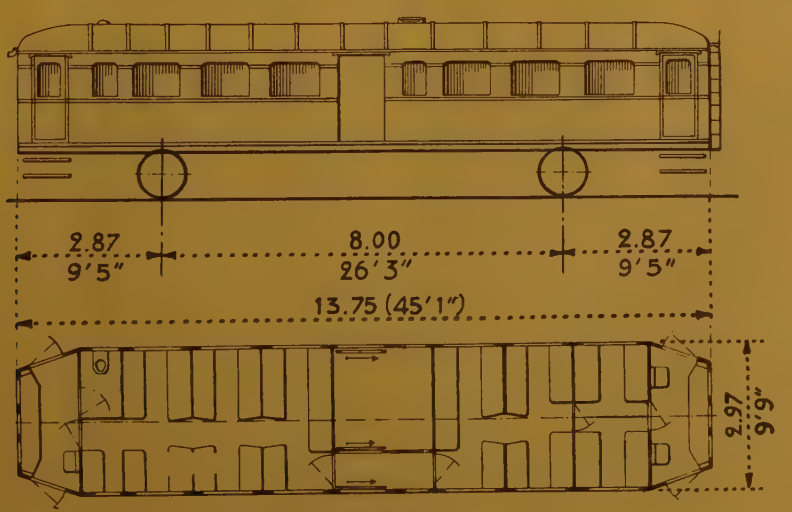


Fig. 128. — Ganz four-wheeled rail motor coach.

TABLE 130.

EXAMPLES OF T OR TT TRAIN SERVICES WORKED BY RAIL MOTOR COACHES OR RAIL BUSES (fig. 127).

SERVICE.	Distance		Time of departure.	Time spent.	Speed		Number of stops.	Type of vehicle.
	Km.	Miles.			Km./h.	Miles/h.		
STEAM RAIL MOTOR COACHES.								
Liége Guill.-Verviers	25	15.5	12.47 a. m. 8.11 a. m.	0.34 0.45	44.1 33.3	27.4 20.7	2 11	Sentinel 100 H.P. Do.
Do. -Esneux-Comblain-au-Pont.	25	15.5	R 9.33 a. m.	0.40	37.5	23.3	14	Do.
Verviers Est-Pepinster-Spa	19	12	5.00 a. m.	0.39	30.0	18.6	13	Birmingham 175 H.
DIESEL RAIL MOTOR COACHES.								
Antwerp Central-Esschen	33	20.5	10.40 p. m.	0.51	39.2	24.4	12	Mayb. mech. 175 H.
Brussels Nord-Malines	21	13	8.44 a. m.	0.35	36.0	22.4	6	Do.
Ghent St. P.-Alost	27	17	R 1.14 p. m.	0.42	38.6	24.0	7	Eva mech. 175 H.P.
Do. -Selzaete	27	17	2.35 p. m.	0.44	36.9	22.9	10	Maybach 175 H.P.
Do. -Eecloo-Bruges	52	32	5.54 a. m.	1.19	27.9	17.3	20	Eva mech. 175 H.P.
Do. -Tête de Flandre	58	36	7.54 a. m.	1.45	33.1	20.6	22	Do.
Do. -Thielt-Ingelmunster	41	25	5.53 a. m.	1.18	31.5	19.6	17	Maybach 175 H.P.
Do. -Renaix	30	24	8.32 a. m	1.00	39.0	24.2	13	Do.
Soignies-Haine-Saint-Pierre	27	17	8.41 a. m.	0.47	34.3	21.3	12	Do.
Manage-Ottignies-Wavre	41	25	12.17 p. m.	1.07	36.7	22.8	13	Do.
Piéton—Merbes-Sainte-Marie.	14	8.7	7.19 a. m.	0.18	47.1	29.3	5	Ganz 130/150 H.P.
FAST DIESEL TWIN RAIL MOTOR COACH.								
Ghent-St. P.-Brussels Midi	52	32	10.40 a. m.	0.33	94.5	58.7	0	Twin elect. 410 H.

Brussels, and into Ghent, during which the speed is necessarily reduced. The run has already been made in 28 minutes and 28 1/2 minutes and it would be easy to keep up a regular service in 30 minutes, i.e. at an overall speed of 104 km. (64.6 miles) an hour.

After a continuous mileage of 25 000 km. (40 000 km.), the vehicle was taken out of service for a fortnight (September 1934). During this time ordinary rakes of stock hauled by steam locomotives were used without any extra time being allotted to them.

The fuel consumption of the rail motor coach is relatively low.

These encouraging results have led the Company to order 8 triplet motor coaches, with two 410-H.P. engines each.

XXIII-3. — **Motor bus services** (fig. 130). — The *Belgian Railways* operate 16 motor bus services, either to fight existing services by following slightly

Table 131.

LEADING DIMENSIONS OF DIESEL RAIL MOTOR COACHES OR SETS.

Date.	Builder of vehicle.	Builder of engine.	Power. Norm	Power. Max.	Revs. per min.	Kind of transmission.	Speed Km.	Speed Miles.	Number of wheels.	Carrying capacity.
1930	E. V. A. (Berlin) .	Maybach.	175	180	1400	Mech. Maybach.	80	50	4 + 4	92 + lugg.
Do.	Deva, Vesteras .	Burmeister and Wain.	200	200	4850	Elect. Asea.	80	50	4 + 4	80
1933	Brugeoise N. D. .	Maybach.	175	180	1400	Mech. Maybach.	80	50	4 + 4	104 + 50
1934	Ganz	Ganz.	120	150	1200	Mech. Ganz.	65	40	4	60
Do.	La Dyle, Louvain.	M.A.N.	140	160	1400	Mech. T.A.G.	65	40	4	60
Do.	Brugeoise, N. D. .	Maybach.	210	220	1400	Mech. Maybach.	80	50	4 + 4	104 + lugg.
Do.	Do	Do.	210	220	1400	Elect. A.C.E.C.	80	50	4 + 4	
Do.	Do	Do.	410	430	1400	Elect. Siemens.	120	75	4 + 4 + 4	196
Do.	S. E. M. Brussels.	Carels, Ghent.	250	260		Mech. S.L.M.	90	56	4 + 4	104 + lugg.
	Do	Do.	350	400	1450		80	50	4 + 4	104 + lugg.

BUILDER.	Wheels, diameter.	Bogies. Wheel base.	Bogies. Distance between centres.	Overall dimensions. Length.	Overall dimensions. Width.	Overall dimensions. Height.
E.V.A., Maybach .	0.966 m. (3 ft. 2 in.)	2.500 m. (8 ft. 2 7/16 in.)	15.500 m. (50 ft. 10 1/4 in.)	21.700 m. (71 ft. 2 23/64 in.)	...	...
Deva, B. and W. .	0.966 m. (3 ft. 2 in.)	2.500 m. (8 ft. 2 7/16 in.)	15.500 m. (50 ft. 10 1/4 in.)	20.700 m. (67 ft. 11 in.)	2.940 (9 ft. 7 3/4 in.)	4.200 m. (13 ft. 9 11/32 in.)
Brugeoise, Maybach	0.870 m. (2 ft. 10 1/4 in.)	3.500 m. (11 ft. 6 in.)	15.400 m. (50 ft. 6 5/16 in.)	22.000 m. (72 ft. 3 in.)	2.985 (9 ft. 9 1/2 in.)	3.765 m. (12 ft. 3 in.)
	0.970 m. (3 ft. 2 1/4 in.)	2.200 m. (7 ft. 2 5/8 in.)	...	...	...	...
Ganz	0.920 m. (3 ft. 1/4 in.)	...	8.000 m. (26 ft. 3 in.)	13.740 m. (45 ft. 1 in.)	2.990 (9 ft. 9 23/32 in.)	4.080 m. (13 ft. 4 5/8 in.)
Brugeoise, Maybach	0.970 m. (3 ft. 2 1/4 in.)	3.500 m. (11 ft. 6 in.)	36.250 m. (118 ft. 11 1/8 in.)	44.350 m. (145 ft. 6 in.)	2.915 (9 ft. 6 25/32 in.)	3.600 m. (11 ft. 9 3/4 in.)

TABLE 132.

MOTOR BUS SERVICES OPERATED BY THE BELGIAN NATIONAL RAILWAYS COMPANY (fig. 130).

ROUTE.	Distance		Time of departure. (1)	Time spent.	Speed.		Number of stops. (2)	Number of services from end to end. (3)
	Km.	Miles.			Km./h.	Miles/h.		
Brussels Nord-Saventhem	11	6.8	6.30 a. m.	0.28	23.5	14.6	4+10	18
Do.	*10*	*6.2*	...	*0.16*	*37.5*	*23.3*	*2*	
Brussels Midi-Louvain	30	18.6	7.00 a. m.	1.05	27.7	17.2	7+32	28
Do. Nord- do.	*30*	*18.6*	...	*0.28*	*64.3*	*40.0*	*0*	
Marche-Rochefort	13	8.0	7.43 a. m.	0.31	12.2	7.6	6+13	4
Roulers-Ypres	25	15.5	5.00 a. m.	0.48	31.2	19.4	5+16	17
	32	*20.0*	*8.29 a. m.*	*0.31*	*62.0*	*38.5*	*2*	
Ingelmunster-Anseghem	25	15.5	7.20 a. m.	0.56	26.8	16.6	9+17	6
Ghent-Deynze	16	10	7.30 a. m.	0.36	26.7	16.5	0+13	6
Do.	*16*	*10*	...	*0.15*	*64.0*	*39.8*	*0*	
Tournai-Peruwelz.	...	...	6.35 a. m.	1.10	...	...	7+26	4
Do.	*11*	*6.8*	...	*0.22*	*30.0*	*18.6*	*1*	
Péruwelz-Leuze	...	...	11.54 a. m.	0.25	...	...	4+11	2
Lessines-Renaix	...	...	6.10 a. m.	0.40	...	...	8+15	5
Tournai-La Glancerie	18	11	6.20 a. m.	0.30	36.0	22.4	9+14	9
Tournai-Esplechin	10	6.2	10.30 *a. m.*	0.30	20.0	12.4	5+ 9	—
Tournai-Leuze	...	...	6.30 a. m.	0.40	...	...	7+10	3
Do.	*18*	*11*	...	*0.15*	*72.0*	*44.7*	*0*	
Binche-Manage	17	10.5	7.05 a. m.	0.45	22.7	14.1	9+17	6
Do.	*19*	*12*	...	*0.50*	*22.8*	*14.2*	*8*	
Braine l'Alleud-Hal	15	9	7.00 a. m.	0.35	28.6	17.8	5+ 2	8
Brussels Nord-Charleroi	54	33.5	8.25 a. m.	1.45	30.9	19.2	7+31	7
Do. Midi- do.	*56*	*35*	...	*0.44*	*76.4*	*47.5*	*0*	
Châtelineau-Châtelet-Maredsous	34	21	2.35 p. m.	1.21	25.2	15.7	9+ 9	1

different routes than the railway system, or to replace services which have become too expensive to operate owing to lack of local patronage.

XXIII-4. — **Services operated by the Belgian National Light Railways Company.** — A great number of Belgian secondary lines, altogether 4 720 km. (2 933 miles) (4), are operated by this Company which for a long time was very prosperous and played a great part in developing the country. It suffered more severely than the *Belgian National Railways Company* as it operates no main

(1) Time of departure of the first bus.

(2) Number of fixed stops plus the number of supplementary stops.

(3) Excluding services which are only run on Sundays or certain week days.

(4) On the 31st December 1933, out of 5 272 km. (3 276 miles) of lines worked under concession.

TABLE 133.

SOME EXAMPLES OF THE SPEEDS ATTAINED ON THE SERVICES OPERATED BY THE BELGIAN NATIONAL LIGHT RAILWAYS COMPANY.

ROUTE.	Distance		Time of departure.	Time spent.	Speed.		Number of stops.
	Km.	Miles.			Km./h.	Miles/h.	
STEAM TRAINS.							
Bruges-Dixmude	43	27	3.45 p. m.	1.25	30.3	18.8	13
Dixmude-Roulers	27	17	5.15 a. m.	1.17	21.0	13.0	19
Cockelaere-Leke	6	3.7	7.18 p. m.	0.12	30.0	18.6	
Turnhout-Sichem	51	32	9.40 a. m.	2.46	18.4	11.4	29
ELECTRIC SERVICES.							
Bruges station-Heyst	23	14	7.08 a. m.	0.47	29.4	18.3	10
Ostend-La Panne	34	21	8.15 a. m.	1.19	25.8	16.0	17
Brussels (P. N.)-Ninove	23	14	8.15 a. m.	0.55	25.1	15.6	20
Braine l'Alleud-Wavre	23	14	7.00 a. m.	1.00	23.0	14.3	11
Brussels (Pl. R.)-Leerbeek	20	12	8.05 a. m.	0.58	20.7	12.9	18
Antwerp-Malines	27	17	8.00 a. m.	1.25	19.1	11.9	15
RAIL MOTOR CARS.							
Turnhout-Poppel	18	11	6.12 a. m.	0.40	27.0	16.8	12
Do. -Arendonck, douane	17	10.5	11.05 a. m.	0.50	20.4	12.7	10
Berchem-Oostmalle	19	11.8	7.44 a. m.	0.46	24.8	15.4	7
Louvain-Jodoigne	29	18	8.15 a. m.	1.15	23.0	14.3	12
Furnes-Proven (Poperinghe)	28	17.4	7.30 a. m.	1.03	36.6	22.7	10
ROAD MOTOR BUSES.							
Ostend-Furnes	32	20	4.20 p. m.	1.10	27.4	17.0	12
Namur-Perwez	25	15.5	7.35 a. m.	1.20	18.8	11.7	26
Spa, station — Malmédy, stat.	29	18	9.30 a. m.	1.10	24.9	15.5	22
Houffalize-Manhay	24	15	11.30 a. m.	1.00	24.0	14.9	11
Do. -Bastogne, Etat	34	21	7.10 a. m.	1.59	17.2	10.7	25
Dixmude-Rousbrugge	33	20.5	10.05 a. m.	1.35	20.8	12.9	21
COMBINED SERVICES STEAM AND ROAD MOTOR BUSES.							
Knocke-Sluys	8	5	8.21 a. m.	0.29	18.6	11.6	3
Ostend Quay-La Panne	34	21	8.15 a. m.	1.19	25.8	16.0	16
Lierneux-Vielsalm	15	9	4.05 p. m.	0.45	20.0	12.4	10

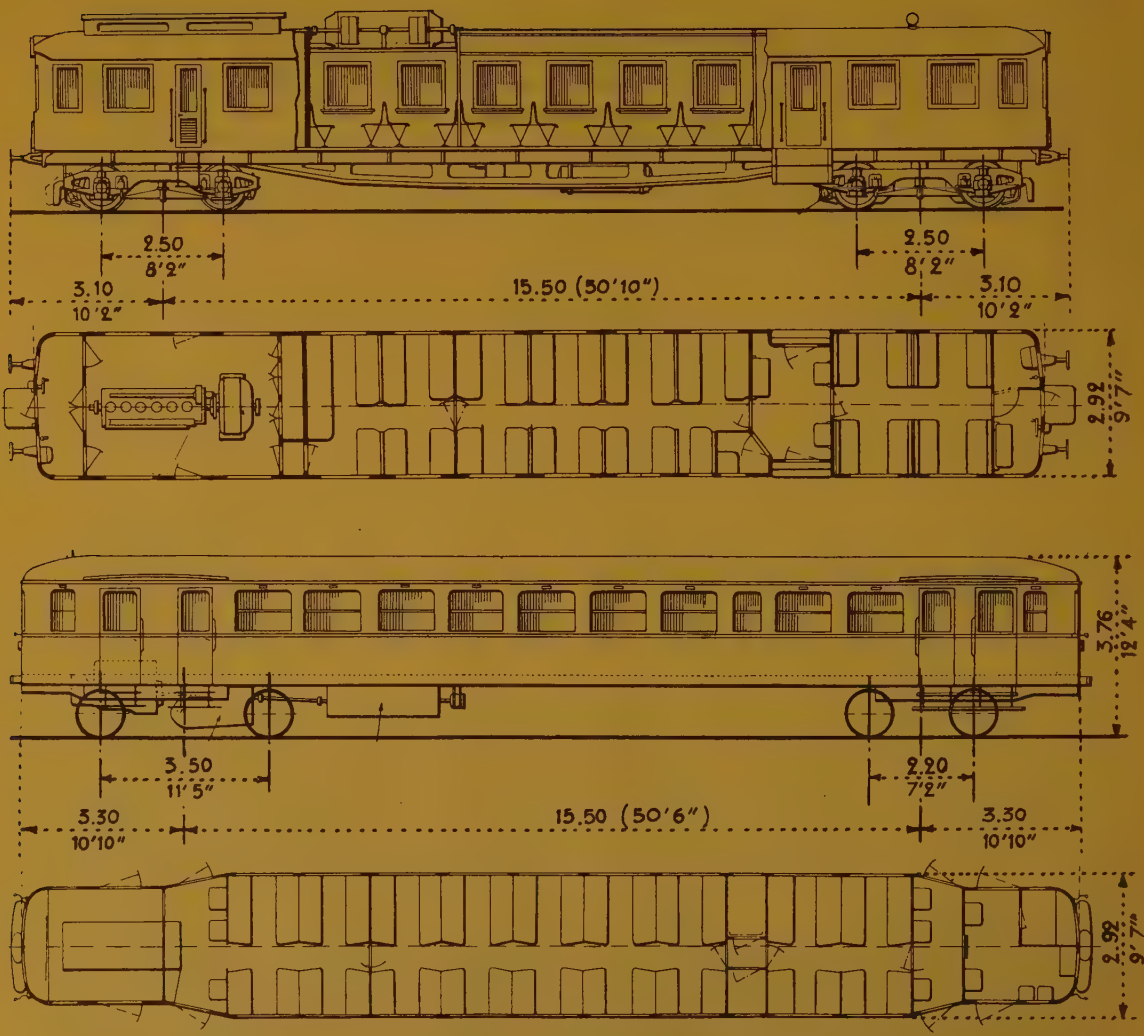


Fig. 129. — Diesel rail motor coaches of the Belgian National Railways.
a) with mechanical transmission, 175 H.P. *b)* with electric transmission, 200 H.P.

line services, and so it has endeavoured to improve its services by electrifying certain lines (at the present time 1 227 km. = 762 miles), which enabled it to get higher speeds, but of course meant additional financial burdens.

It has also introduced a certain number of motor bus services :

436 km. (271 miles) of lines with heavy capital charges;

2 753 km. (1 711 miles) of lines with low capital charges.

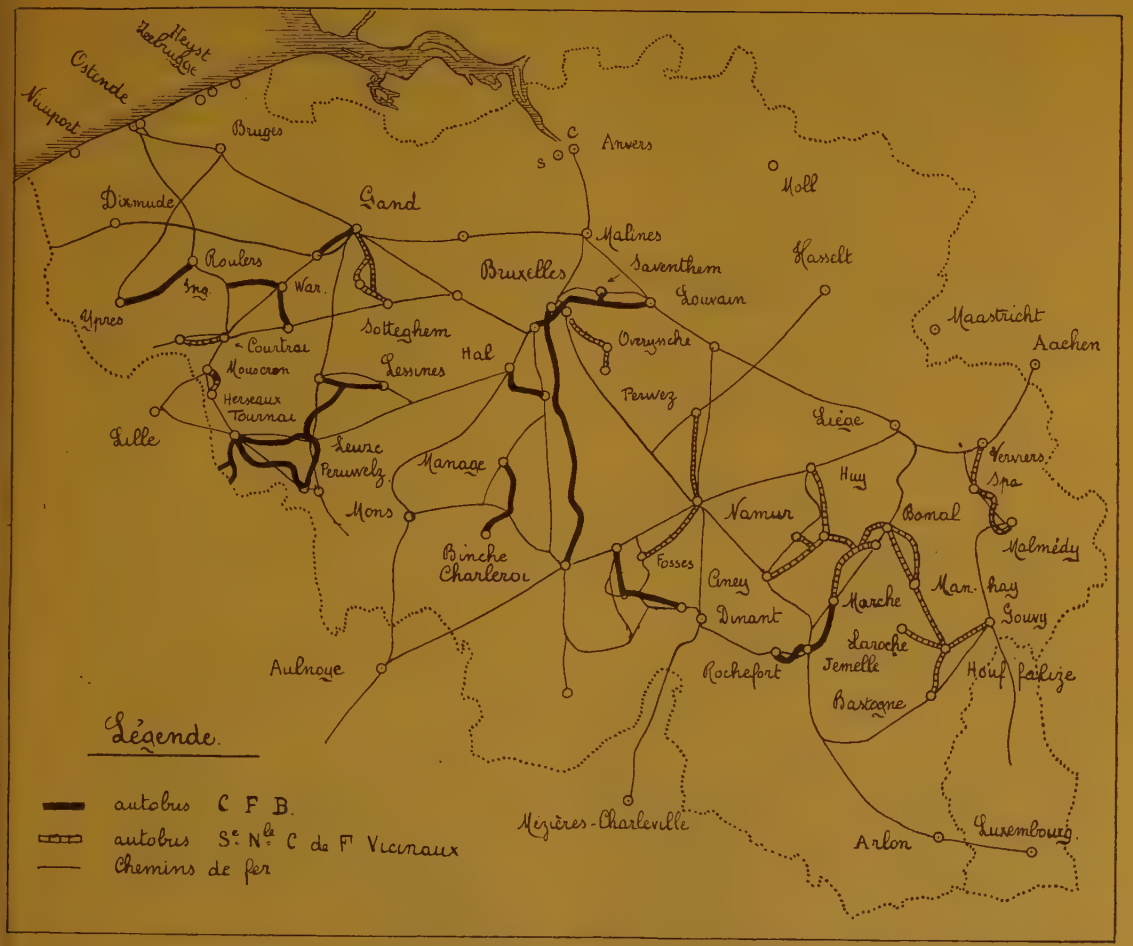


Fig. 130. — Map showing the motor bus services operated by the Belgian National Railways Company and the Belgian National Light Railways Company.

Although the services it operates itself have all shown a deficit, the lines handed over to contractors have paid.

The use of rail motor coaches seems to be satisfactory, whilst being much cheaper than electrification, and 100 further 4-wheeled units are on order.

The great development of secondary lines in certain parts of the country, such as the north-east of the Antwerp district and part of Flanders, has had one drawback : the places served by them are too far apart in time, because the overall speed of the trains is only 20 km. (12.4 miles) an hour. The original light railway system should have been completed by standard gauge lines while the traffic was developing, or such lines might even have been substituted for the former. The fact that this was not done in time is without doubt one of the reasons of the great development of the road motor

services in these districts, while the lack of fast communications with the capital and other parts of the country has had political results partly attributable to the same reasons.

CHAPTER XXIV.

Belgian services of the International Sleeping-Car Company.

This Company, formed at Liége in 1873 by Georges Nagelmakers and since reorganised, has had its headquarters in Brussels since 1876, so that it is not surprising that its Belgian services developed very rapidly (fig. 131).

Its Ostend-Cologne service was one of the earliest, and its express trains have run over all the main arteries of the country for many years.

On the 1st June 1894, the « Ostend-Vienna Express » was inaugurated, and in 1896 it was extended to Carlsbad and Constantinople.

In the meantime an « Ostend-Trieste Express » had been introduced in 1895 to meet the Alexandria boats; at first it included a rake for Fiume.

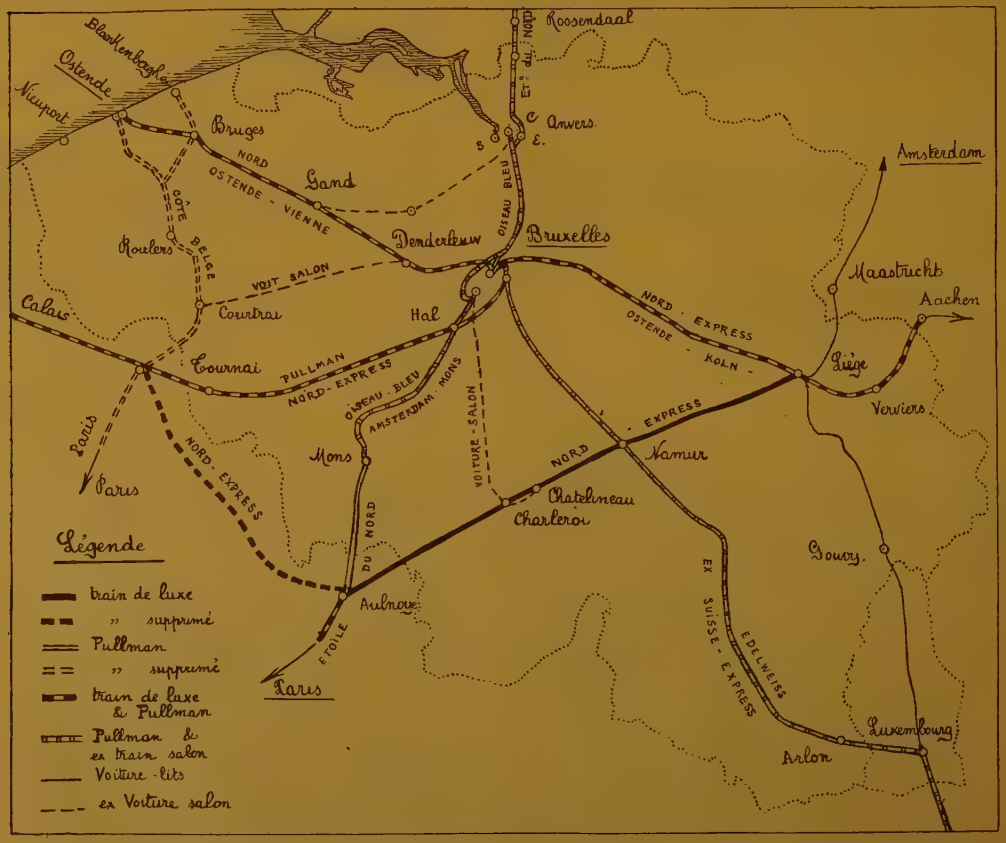


Fig. 131. — Map showing the Belgian services of the International Sleeping-Car Company.

From 1898 to 1902, all these trains also included a Calais-Brussels section (1).

In May 1896, the « Nord-Express » was created, which ran from Ostend to Berlin and into Russia. A section from Calais joined the main train at Brussels, and another from Paris via Namur, at Liége.

In 1901, a « Suisse Express » was introduced between Ostend (and Amsterdam), Basle and Lucerne, making connection for the Engadine with the « Suisse Express » from Calais, Paris and Amsterdam (2).

Since the war, Pullman trains have been introduced :

From NORTH TO SOUTH. — After an unsuccesful experiment with an « Amsterdam-Mons Express » (1900 to 1904) (3) the « Etoile du Nord » (1928) took over this service from Amsterdam to Paris. From Antwerp it is doubled by the « Blue Bird » (1929) and an extension of this latter train to Rotterdam is under consideration.

NORTH to SOUTH-EAST. — The « Edelweiss » from Amsterdam to Basle and Switzerland (Lucerne and Zurich) is run via Strasbourg, over the route formerly taken by the « Suisse Express ».

EAST to WEST. — Two Pullman expresses, one from Ostend to Cologne (1929), and the other from Calais to Brussels (1928) are worked over this route.

One of them was, when started, an important innovation, so it was booked on a faster schedule than the trains already running. But as these trains made good and became heavier, they were out-distanced by trains composed of lighter stock.

However, since the crisis and the resulting drop in traffic, the situation has been reversed, so that the Pullman trains lead in the matter of speed over the lines they serve. The « Ostend-Vienna » and the « Nord Express » have now, during the summer season, been amalgamated with other fast express trains, so that they are too heavy to attain such high speeds. In winter, they run as a single « train de luxe » between Ostend and Liége.

The Calais portion, which was always competitive, has never been a profitable venture, and only continues to be run to offset the trains from Ostend. It originally ran between Calais and Brussels in 1889 in connection with the ephemeral « Club Train ».

It next ran along a different route and then comprised a sleeping-car, a dining-car and a van which, starting from Calais, joined up at Jeumont with the Paris-Berlin « Nord Express ». To do this it had to maintain a very high speed over the French section of the run, and very few passengers used it. Since the war, it has been deemed sufficient to detach a sleeping car from the « Nord Express » at Brussels, and send this to Calais by means of the « Brussels-Calais Pullman ». It ran over the western circle to begin with, but for some years has gone via the north eastern circle and the Brussels Q. L.-Hal line, at which latter place it links up with the other route.

Saloon-carriages (fig. 132). — At the beginning of this century, the *International Sleeping-Car Company* introduced

(1) To avoid repetition, we give full details about these trains in the chapters dealing with Austria and Italy.
(2) Cf. Switzerland under the heading *International Sleeping-Car Company*.
(3) Cf. Holland under the heading *International Sleeping-Car Company*.

Table 134

TRAINS OPERATED BY THE INTERNATIONAL SLEEPING-CAR COMPANY, SERVING BELGIUM (fig. 131).

(Obsolete services are shown in italics).

ROUTE.		Distance		Time of departure.	Time spent.	Speed		
Origin.	Destination.	Km.	Miles			Km./h.	Miles/h.	
(2)	INTERNATIONAL ROUTE.	(1)						
Ostend Quay.	Brussels Nord-Cologne . . .	350	218	R 11.08 a. m.	4.45	73.5	45.7	Pullman express.
Ostend Quay.	Brussels N.-Berlin-Warsaw .	1 556	967	8.32 p. m.	21.18	72.9	45.3	« Nord Express ».
	Do. - do. -Riga . . .	2 030	1 261	Do.	34.18	59.3	36.8	Do.
	Do. - do. -Bucharest .	2 663	1 655	Do.	44.30	37.8	23.5	Do.
Ostend Quay.	Bruss. N.-Vienna-Bucharest .	2 504	1 556	Do.	41.30	64.3	40.0	« Ost.-Vienna Exp. ».
	Do. - do. -Istanbul . .	2 767	1 719	Do.	58.17	47 5	29.5	Do.
	Do. -Karoly Vary . . .	1 021	634	Do.	18.59	32.2	20.0	« Ostend-Carlsbad ».
Ostend Quay.	*Bruss. Q.-L.-Basle-Lucerne* .	713	443	*4.35* p. m.	*15.35*	*45.8*	*28.5*	« *Suisse Express* ».
Calais Mar.	Bruss. Q.-L. and Nord . . .	226	140	R 9.00 a. m.	2.54	78.0	48.5	Pullman express.
	Do. -Berlin-Warsaw .	1 665	1 035	R 12.35 p. m.	23.19	71.3	44.3	« Nord Express ».
Boulogne Mar.	Do. and Nord . . .	258	160	...	...	...	...	*In winter.*
Paris Nord.	Liége (Berlin, Riga, etc.) . .	367	228	**7.15** p. m.	**3.56**	**93.3**	**58.0**	« Nord Express ».
Paris Nord.	Bruss. M.-Antw. E.-Amsterdam.	546	339	R 12.55 p. m.	6.50	80.0	49.7	« Etoile du Nord ».
Paris Nord.	Bruss. M.-Antw. Central . . .	362	225	R 9.46 a. m.	4.14	85.5	53.1	« Blue Bird ».
Amsterdam.	Bruss. N. and Q.-L.-Basle-Zurich	910	565	R 7 22 a. m.	13.07	69.3	43.1	« Edelweiss ».
	Bruss. N. and Q.-L.-Basle-Lucerne	916	569	R 7.15 a. m.	13.14	69.2	43.0	Do.
Amsterdam.	*Bruss. M.-Mons*	301	187	R *4.59* p. m.	*4.59*	*60.5*	*37.6*	« *Amsterdam-Mons* ».
	BELGIAN SECTION.							
Ostend Quay.	Bruss. N.-Aix-la-Chap. (Col.) .	273	170	R 11.08 a. m	3.43	73.5	45.7	Pullman express.
Do.	Do. -Herbesthal (Cologne) .	257	160	4.42 p. m.	3.32	72.7	45.2	Do.
		Do.	Do.	8.32 p. m.	3.35	71.7	44.6	« Ost.-Vienna Exp. ».
Do.	Bruss. N.-Aix-la-Chap. (Col.) .	273	170	Do.	4.12	65 3	40.6	« Nord Express ».
	Brussels Nord	117	73	Do.	1.21	86.7	53.9	Do.
		Do.	Do.	*7.44* p. m.	*1.16*	*92.4*	*57.4*	Do. *(winter)*.
		Do.	Do.	2.33 p. m.	1.20	87.8	54.6	Pullman; 1 stop.
	Bruss. Nord-Liége Guill. . . .	100	62	R **1.13** p. m.	**1.12**	**83.3**	**51.8**	Do.
	Bruss. Nord-Herbesthal . . .	140	87	6.15 p. m.	1.59	70.7	43.9	Do. 2 stops.
Ostend Quay.	*Bruss. Q.-L.-Bettingen* . . .	324	201	*4.35* p. m.	*6.25*	*50.5*	*31.4*	« *Suisse Express* ».
Brussels N.	Tournai (Lille)	90	56	**9.00** a. m.	**1.13**	**73.9**	**45.9**	Pullman express.
Roosendaal.	Bruss. N.-Luxemburg (Switz.).	310	193	9.47 a. m.	4.33	60.5	37.6	« Edelweiss ».
	Antwerp E.-Bruss. N. . .	43	27	R **10.01** a. m.	**0.40**	**65.0**	**40.4**	Do.
	Bruss. N.-Namur	62	39	**10.49** a. m.	0.52	**71.5**	**44.4**	Do.
	Namur-Luxemburg	164	102	**11.45** a. m.	**2.15**	**72.9**	**45.3**	Do.
	Bruss. N.-Luxemburg . . .	226	140	10.49 a. m.	3.10	71.4	44.3	Do. 1 stop.
Roosendaal.	Bruss. Midi-Paris Nord . .	402	250	3.01 p. m.	4.44	84.9	52.8	« Etoile du Nord ».
	Roosendaal-Brussels Midi .	91	57	Do.	1.20	68.3	42.4	Do. 1 stop.
	Antwerp E.-Brussels Midi .	51	32	**3.13** p. m.	**0.47**	**65.1**	**40.5**	Do.
	Brussels Midi-Paris Nord .	311	193	R **11.25** a. m.	**3.11**	**97.7**	**60.8**	Do.
Paris Nord.	Liége Guill. (Cologne) . . .	367	228	**7.15** p. m.	**3.55**	**93.7**	**58.2**	« Nord Express ».

(1) Cf. note about distances at the beginning of paragraph XXII-1.

(2) For the « *Ostend-Trieste Express* » see under Italy.

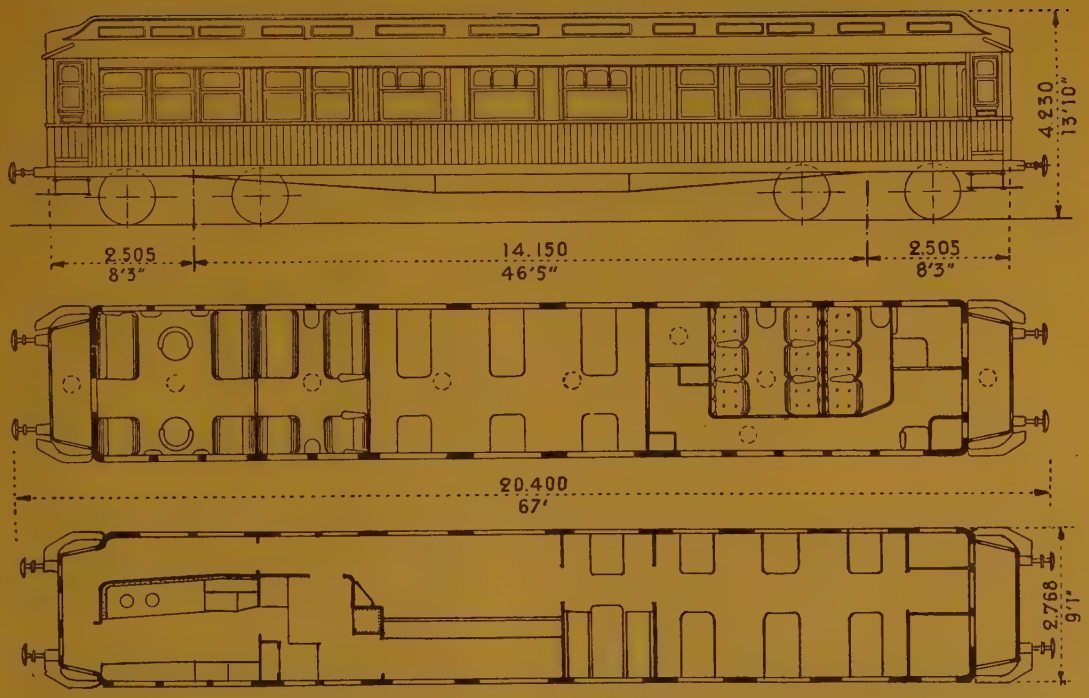


Fig. 132. — *a)* Elevation and plan of the saloon-carriages of the International Sleeping-Car Company; *b)* Plan of the buffet cars.

The elevation of the latter is identical with the former, but the bogie wheel base has been increased by 0.50 m.

in Belgium some thirty saloon-carriages, but these were soon after sold to the Belgian State Railways who let the *Sleeping-Car Company* continue to operate them. The carriages ran over various lines, and, during the summer season, complete trains (ancestors of the Pullman trains), were even made up with them from Brussels to Ostend or Blankenberghe. Furthermore, they were even included in certain suburban services such as tramway-trains from Brussels Q. L. to Groenendael. These services, which were suppressed after the war and have been succeeded by the Pullman services, are shown in table 135.

This taking over by the *Belgian State Railways* of *International Sleeping-Car Company* stock is not the only instance of stock being bought from this Company. Besides the stock confiscated by the Germans during the war, the *London Midland and Scottish* Railway's purchase of Pullman dining cars on its Scotch system, when the Pullman contract expired at the end of last year, should be specially mentioned. These 22 vehicles were bought for £ 21 000 (1) which was a loss of £ 152 000 on the cost price, less amortisation. At the present

(1) In December, 1933.

TABLE 135

SALOON-CARRIAGE SERVICES IN 1911 AND 1914.

SERVICES.	1911	1914
BRUSSELS TO :		
Antwerp	13 + 1 to Roosendaal.	13 + 1
Courtrai, Lille	1	1 + 2 to Lille.
Midi, Charleroi	3	2 + 1 to Châtelineau.
Ostend	3 + 1 from Jemelle.	12 + 2 from Arlon.
Blankenberghe	—	2
Heyst	—	1
Arlon	5 + 1 to Luxemburg.	4 + 2 to Luxemburg.
Verviers	7 + 1 to Liége.	8 + 1 to Liége.
ANTWERP TO :		
Ostend	1	—

time the question of the revaluation of rolling stock is particularly difficult.

Buffet-cars. — For the last two years such vehicles (fig. 132*b*) have been in service between :

Brussels and Liége,
Herbesthal and Calais,
Luxemburg and Blankenberghe.

These vehicles are old dining cars altered for the purpose (1).

3rd-class sleeping cars. — These are operated on the following lines :

from Brussels to Basle,
from Amsterdam to Brussels and Paris Nord.

Sleeping-cars for England. — It seems likely that certain sleeping-car trains may eventually be ferried across from Zeebrugge to Harwich. The vehicles will

(1)

TABLE 136.

LEADING DIMENSIONS OF THE OLD SALOON-CARRIAGES AND THE BUFFET-RESTAURANT CARS.

Length of frame (including vestibules)	19.160 m.	(62 ft. 10 3/8 in.).
Length of body	17.460 m.	(57 ft. 3 1/2 in.).
Length of body over buffers	20.400 m.	(66 ft. 11 in.).
Exterior body width	2.854 m.	(9 ft. 4 3/8 in.).
Exterior height	4.230 m.	(13 ft. 10 1/2 in.).
	2.500 m. —	(8 ft. 2 7/16 in.) —
Bogie wheel base	3.000 m.	(9 ft. 10 1/8 in.).
Distance between bogie centres	14.150 m.	(46 ft. 5 1/8 in.).
Number of seats	41 or 24.	

have to be smaller than the continental stock. We show a recent project in figure 133.

Figure 131 shows the whole of the *International Sleeping-Car Company's* train services.

CHAPTER XXV.

Belgian train speeds.

XXV-1. — **The heritage of the past.** — As they were built at the beginning of the railway era, the main lines suffer from the lack of technical knowledge of the pioneers who built them, and technically the locations of most of them are very bad : curves of too small radius, unnecessarily steep gradients, constricted stations, often on a curve, etc. Owing to financial reasons it has not been possible to make good many of these defects, and though some of them have been remedied to a certain extent, correcting them all would have involved relaying the whole system. Consequently it has to be worked as it is, although there are still unduly steep gradients, and too many places at which it is necessary to slow down, thus damaging the overall speed which is lower than it should be after the considerable efforts made on various sections of the lines.

During a debate between French and Belgian engineers on the comparative technical conditions of their railway systems, the French engineers complained of gradients of 1 in 250 and in 200.

A well-known Belgian engineer said in reply that when he had to deal with a gradient of only 1 in 200, it seemed to be a down gradient to him... This quip shows that on the Belgian system lines on the level or easily graded are the exception.

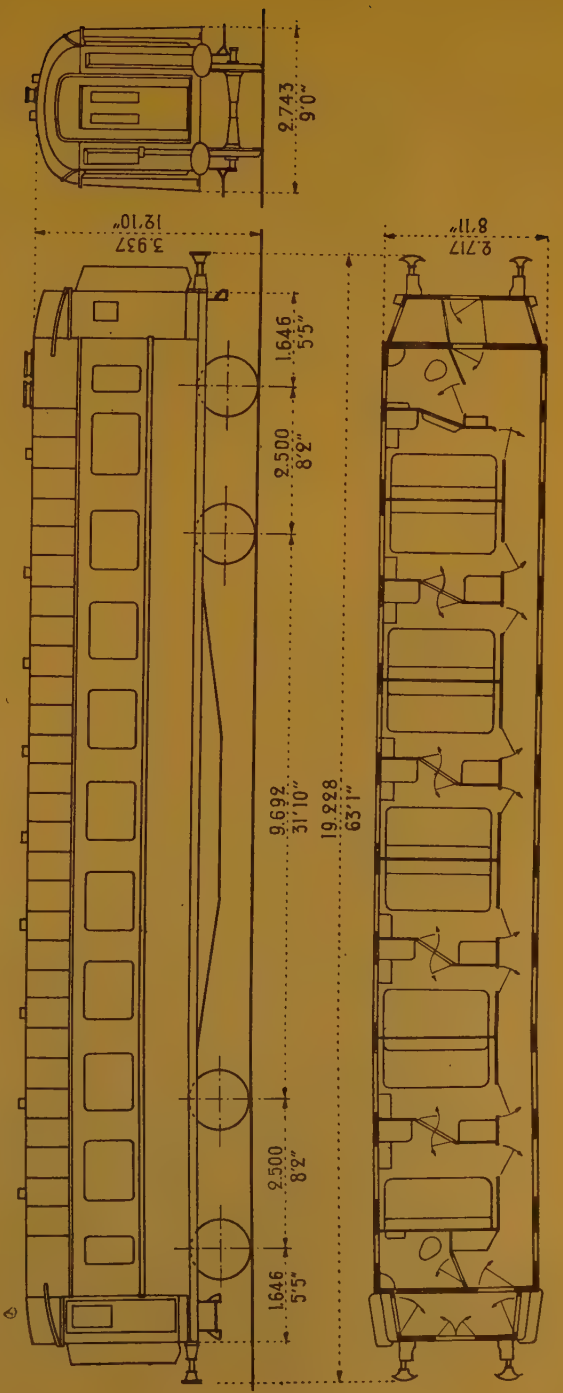


Fig. 133. — Projected sleeping cars (1934) of the *International Sleeping-Car Company*, suitable for the English loading gauge.

Out of the 4 828 km. (3 000 miles) operated there are :

Level		21 %.
With gradients	of less than 1 in 200	42 %.
	of more than 1 in 200 to 1 in 100.	19 %.
	of more than 1 in 100 to 1 in 40.	17 % i.e. 834 km. (518 miles).
	of more than 1 in 40	0.2 % i.e. 7 km. (4.35 miles).

11 % of the system is on curves of less than 500 m. (25 chains) radius; 25 % on curves of over 500 m., and 64 %, i.e. two thirds, on the straight.

In addition, SPEED LIMITS laid down by the permanent way department are more frequent and more rigorous than elsewhere. They vary from 60 to 120 km. (37.3 to 74.6 miles) an hour, while rail motor coaches are allowed to run at 130 km. (80.8 miles) an hour between Brussels and Ghent.

TABLE 137.

MAXIMUM SPEED ON THE OPEN TRACK.

	Km./h.	Miles/h.	
Brussels to Ostend	120	74.6	
Do. to Courtrai	90	56.0	
Do. to Termonde	70	43.5	
Do. to Antwerp	120	74.6	
Do. to Liége	120	74.6	
Liége to Hergenrath	90	56.0	
Brussels-Arlon	100	62.0	« Edelweiss ».
	100	62.0	T trains between Groenendael and Boitsfort.
	90	56.0	other trains.
Charleroi-Namur	90	56.0	
Liége-Gouvy	60	37.0	
Brussels-Charleroi	100	62.0	
Brussels-Mons	120	74.6	
Brussels-Tournai-Blandain	120	74.6	

On the Ans gradient the speed allowed is only 25 km. (15.5 miles) an hour in the case of express trains and 18 (11.2 miles) for other trains.

There are still more drastic restrictions NEAR LARGE STATIONS, of course, especially as many of them are badly situated. Thus on the Ostend line speed is restricted to 60 km. (37.3 miles) an hour at Bruges, which is excusable as this is an old station built on a curve, but the limitation to 60 km. an hour when running through the new station of Ghent St. Peter can be criticised.

We have already pointed out how badly situated are the stations of Ath (speed limit 50 km. = 31 miles) and Mons (60 km. = 37.3 miles at the north side and 40 km. = 25 miles at the south). Malines station must not be run through at more than 70 km. (43.5 miles) an hour. On the other hand 100 km. (62 miles) an hour is allowed through Louvain and 120 (75 miles) at Tirlemont.

As far as the unfortunate Luxemburg line is concerned, the following speeds are allowed : 50 km. (31 miles) an hour at Brussels Q. L., 40 km. (25 miles) an hour at Gembloux, Namur (except in the case of the « Edelweiss » for which the

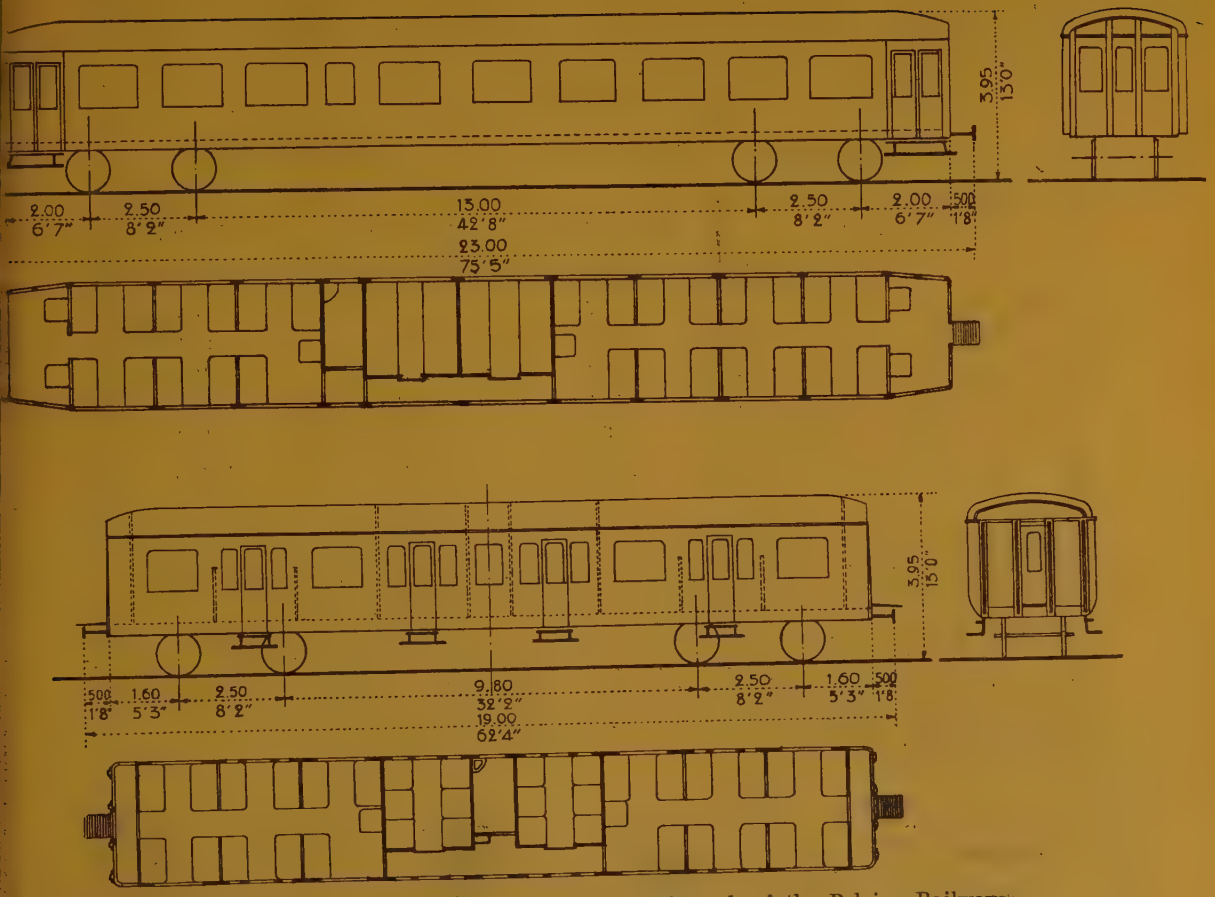


Fig. 134. — *a)* 22-m. (72 ft. 2 1/8 in.) metal coach of the Belgian Railways; *b)* 18-m. (59 ft. 5/8 in.) metal coach for home service.

limit was raised to 55 and 60 [34.2 and 37.3]), and Jemelle.

There are still many SWING BRIDGES, which are usually crossed at speeds of 60 km. (37.3 miles) an hour. However, at Malines, the speed is limited to 50 km. (31 miles), and at Louvain to 40 km. (25 miles). On the other hand, at Oudenburg, between Bruges and Ostend, 80 km. (50 miles) an hour is allowed.

These restrictions, more than anything else, prevent high average speeds being achieved, in spite of running speeds of nearly 120 km. (75 miles) an hour. It is to be regretted that these great efforts on the open track should be rendered ineffective by far too many obligatory slowings down, and that no systematic programme to suppress them is being undertaken as in several other countries.

On the other hand, a great part of the rolling stock taken over from the State Railways or handed over as war reparations is too old :

TABLE 138.

AVERAGE AGE OF THE ROLLING STOCK ON THE 31st-12-1932.

Average age.	Locomotives.	Carriages.	Wagons.
	← % of total. →		
Under 10 years	1.7	0.2	5.7
10 to 20 years	42.3	15.0	23.0
20 to 30 years	40.4	41.7	40.0
30 to 40 years	12.5	28.5	21.2
Over 40 years	3.1	14.6	10.1
TOTAL STOCK . .	3 730 *(standard).*	8 473	114 065

The *Belgian National Railways Company* is carrying out a much needed modernisation policy. The new metal rolling stock is made to standard dimensions, the vehicles being 22 or 18 m. (72 ft. 2 1/8 in. or 59 ft. 5/8 in.) long according as they are intended for international or home traffic (fig. 134).

The new coaches have special anti-telescoping ends to protect the passengers. These ends are formed of two end walls of very rigid steel pressings and rolled sections connected by pressed cross members, and by a double steel plate casing (fig. 135).

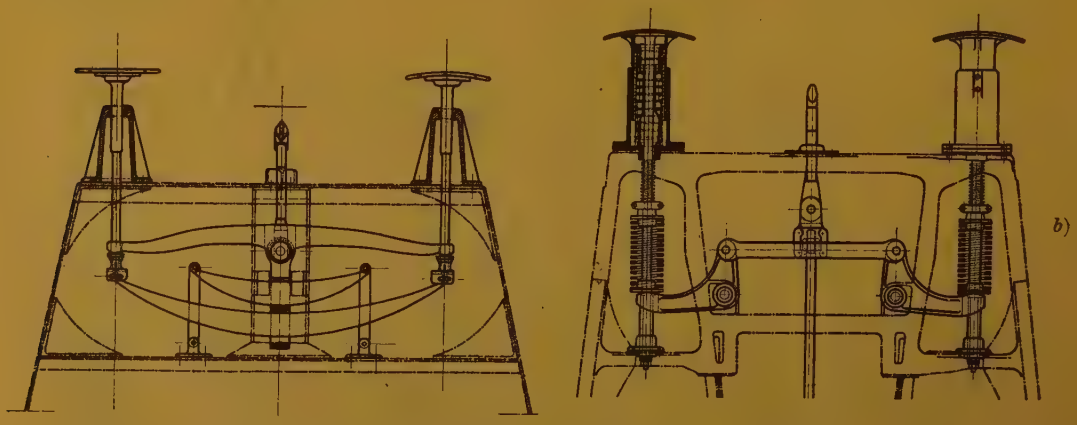


Fig. 135. — Diagram showing the buffer and draw gear on :
a) the old carriages;
b) the new all-metal carriages.

The leading dimensions are as follows:

TABLE 139.

LEADING DIMENSIONS OF THE NEW ALL-METAL ROLLING STOCK (fig. 134).

ALL-METAL VEHICLES.	22 m. (72 ft. 2 1/8 in.).	18 m. (59 ft. 5/8 in).	14.30 m. (46 ft. 11 in.).
Length, overall	23.20 m. (76 ft. 1 7/16 in.)	...	15.600 m. (51 ft. 2 in.)
Width, do.	2.960 m. (9 ft. 8 9/16 in.)	2.930 m. (9 ft. 7 11/32 in.)	...
Height, do.	3.950 m. (12 ft. 11 1/2 in.)	3.950 m. (12 ft. 11 1/2 in.)	3.950 m. (12 ft. 11 1/2 in.)
Length of body	22.000 m. (72 ft. 2 1/8 in.)	18.00 m. (59 ft. 5/8 in.)	14.300 m. (46 ft. 11 in.)
Wheel diameter	1.010 m. (3 ft. 3 3/4 in.)	1.010 m. (3 ft. 3 3/4 in.)	1.010 m. (3 ft. 3 3/4 in.)
Bogie wheel base	2.500 m. (8 ft. 2 7/16 in.)	2.500 m. (8 ft. 2 7/16 in.)	2.500 m. (8 ft. 2 7/16 in.)
Distance between bogie centres.	15.500 m. (50 ft. 10 1/4 in.)	12.300 m. (40 ft. 4 9/32 in.)	9.000 m. (29 ft. 6 3/8 in.)
Wheel base	18.000 m. (59 ft. 1 in.)	14.800 m. (48 ft. 6 23/32 in.)	11.500 m. (37 ft. 8 11/32 in.)
Number of seats (3rd cl.) . .	108	97	Brake van.
Do. of tip-up seats . . .	4	...	...
Number of seats (2nd cl.) . .	72	64	...
Do. of tip-up seats . . .	4	...	...
Number of seats (1st & 2nd) .	12 + 52	12 + 44	...
Do. of tip-up seats . . .	6	2	...

XXV-2. — **General.** — WEIGHT OF TRAINS. — The maximum weight of the trains is high, being as much as 600 t. (590 Engl. tons) on the Ostend line (1) and 450 t. (443 Engl. tons) on the Liége line (2) where the trains are hauled by classes 7 and 10 locomotives weighing 131 or 162 t. (128.9 or 159.5 Engl. tons) in working order (3).

On the Luxemburg line the loads of the international expresses (in 1931 and 1932) was 300 to 400 t. (295 to 394 Engl. tons), and of train No. 8, from Brussels Nord to Arlon as much as 500 t. (492

(1) Trains Nos. 15 and 9 from Brussels Nord to Ostend Quay; trains Nos. 54 and 169 in the opposite direction (in 1931/32). At the present time, express No. 55 from Brussels Nord to Ostend still weighs as much as 600 t. (590 Engl. tons) and is hauled by a single class 10 locomotives.

(2) Express trains Nos. 171 and 145 from Brussels Nord to Aix-la-Chappelle, and Nos. 146 and 172, for the return journey.

(3) Class 7 locomotives, weighing 83.48 t. (82.16 Engl. tons) have a tender weighing 47.90 t. (47.14 Engl. tons) in working order. Class 10 locomotives, weighing 98 t. (96.4 Engl. tons), have a tender weighing 64 t. (63 Engl. tons).

Engl. tons) and even 730 t. (718 Engl. tons) with one engine (Whitsun, 1932). These loads have varied since then, but still are, in the case of train No. 8, as much as 250 to 350 t. (246 to 344 Engl. tons), and 540 t. (531 Engl. tons) on Sundays.

In view of the steepness of the gradients, which reach 1 in 62, all these trains are hauled by class 10 or class 5 locomotives. Double heading is only used under the following conditions :

Class 5 (1). More than 600 t. (590 Engl. tons) in summer and 540 t. (531 Engl. tons) in winter.

Class. 10. More than 430 t. (423 Engl. tons) in summer and 387 t. (381 Engl. tons) in winter.

Punctuality of the trains is remarkably good. During 1932 the average time lost per train was only 30 seconds, and this average was spoilt, as everywhere else, by the poorer results during November (45 seconds) and December (35 seconds).

The number of accidents is low. In 1932, there were :

Passengers	killed	4
Do.	injured	50
Do.	carried	190 873 000

i.e. 0.021 killed and 0.282 injured per million passengers carried.

Road traffic accounted, in 1934, for 1 200 people killed.

Publicity. — One of the greatest defects of the Belgian Railways — moreover a general Belgian failing — is the lack of attention paid to publicity, and there are many things worthy of praise if the public, and even in certain cases the specialists, had their attention called to them.

On the other hand, certain defects leap to the eye, and as far as the matter we are dealing with is concerned, such is the deceleration of certain trains : the 34 minutes taken by the set trains between Antwerp and Brussels was raised to 36 after the war (2) and the 30 minutes from Brussels to Louvain to 31.

Such criticisms might be counterbalanced by calling attention to many remarkable accelerations, thanks to which certain journeys, often over difficult routes, are made at speeds comparable to the best found elsewhere.

The journey from Brussels to Bruges for example is made at 96.4 km. (60 miles) an hour, and 103 km. (64 miles) an hour is the average speed of the 14 daily trains between Ans and Louvain. In spite of this the travelling public only considers that the average speed from Liége to Brussels is 83.4 km. (51.8 miles) an hour, and it is useless to point out that this is already a remarkable feat as, during this run, the Ans gradient, has to be negociated, the swing bridge at Louvain crossed and Brussels run into at reduced speed. The only way to make the public appreciate the magnificent effort made would be to stop one of the expresses serving Ghent or Antwerp, at Ans. As they already stop at Louvain, the loss of time would be very small and the publicity value of this stop would be very great. Would it not be worth while doing this?

(1) In running order the class 5 locomotive weighs 130 t. (128 Engl. tons) and its tender 83 t. (81.7 Engl. tons).

(2) In 1933 these 36 minutes were brought down to 35, after which they were increased to 40 owing to permanent way work being in progress.

XXV-3. — **Services between two towns.** — In order to investigate thoroughly the services between two towns it is not sufficient to quote the fastest trains only : other elements come into play and amongst these, the effective distance, the cost of the journey, and the time taken not only by the express trains but by all the trains in question.

PRICE OF TICKETS. — Even overlooking all free journeys and season tickets of all sorts (particularly workmen's tickets) the Belgian railway ticket rates are still the lowest of western Europe.

COMPARATIVE RATES IN DIFFERENT COUNTRIES

for a distance of 150 km. (93 miles).

COUNTRIES.	Rate of exchange.		1st class.	2nd class.	3rd class.
		Belgian francs.			
Belgium.	...		93.00	64.00	37.00
France.	100 French francs	= 142.00	96.00	64.80	42.25
Germany (1).	1 Reichsmark	= 8.60	113.60	74.85	51.60
Netherlands (1).	1 florin	= 14.60	107.35	85.45	60.60
Switzerland.	1 Swiss franc	= 7.00	157.50	110.25	78.75

According to the « *Journée Industrielle* » (except as far as the rates at present in force in England and France are concerned) the coefficient of increase on a gold basis, for July 1934 as compared with 1914, would be :

France, up to November 1933 .	0.68
England, after going off the gold standard	0.92
Austria	1.03
Belgium	1.16
Germany, according to class .	1.43-1.14-1.50
England, up to 1932	1.50
Switzerland	1.52
Sweden	1.90

These figures are not the amounts actually paid by the passengers as they do not include the transport tax (2).

The JOURNEY TIME TAKEN by the different trains decides whether a daily shuttle service is possible or not. Under similar conditions moreover, it takes the same time to get to places at such different distances from Brussels as Grammont and Tournai, for example, and a map which would take such factors into

(1) Nor do they include the cost of supplements for express trains (D or FD trains).

(2) Mr. E. D. BRANT pointed out in *The Railway Gazette* that this was as high as 32.5 % in France (before Nov. 1933). At that time the taxes were lowered to 12 % (bringing the coefficient of increase to 0.81) which, with an index figure of + 3.4 for the paper-franc or $\frac{3.4}{5}$ for the gold-franc, gave the increase mentioned (0.68), whereas with the present index figure of 4.025, this increase becomes $\frac{4.025}{5} = 0.805$.

consideration would not merely be interesting : it would show in a striking way the accessibility of the capital from the various towns considered.

For this purpose, the situation of all the places which can be reached by through train from Brussels is shown in figure 136 by a little circle. A number of circumferences show how many minutes it takes to get there by train from one of the three Brussels main stations. We have also plotted to the same scale and shown by a large black circle the number of minutes required to get to each of the places on this map by moving them away from the geographical position nearer to or further from Brussels on the line linking them up with the corresponding stations of that city (1).

To be quite exact, the geographical position itself should be altered and replaced by a new one showing the mileage marked off on the radius linking up the geographical position and the Brussels station. We have done this for some of the towns, as an example (2), by showing this 3rd position by two little concentric circles. The distance between the third and first positions is greater according to whether the line is more winding or indirect.

All the places which can be reached from Brussels in the same number of minutes are equidistant. In the case of a speed of 60 km. (37.3 miles) an hour, which is that of the best trains from Brussels to Luttre or Alost, the geographical position and the time situation (black circle) are identical.

In the case of speeds higher or lower than this, the black circles are correspondingly nearer or further from Brussels as the speed is higher or lower, the distance between the circles being (when it is question of the corrected geographical position which we have called the 3rd position) proportional to the difference between the actual speed and a speed of 60 km. (37.3 inches) an hour.

When places are linked up with two of the Brussels stations by express trains, we have called special attention to the fact (3).

AVERAGE TIME FOR A GIVEN JOURNEY. — For the sake of completeness, we have still to examine the position from the point of view not of the shortest journey time between two given places, but of the average time for all express trains, (if there are any) or others in the case of places not served by express trains.

We give below the table of the modifications to be made, to the times we have just considered, for a series of places. We have left out the journey from Brussels to Antwerp which has already been dealt with previously.

It will be seen that the speed of the set trains remains constant in both directions, but this is not so in the case of other trains, the variations of which are often too great.

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(1) We have only drawn the part of the radius connecting up the hollow circle (geographical position) with the black circle (time situation, referred to the minutes scale, such as is shown on the arcs of the circumference).

(2) In particular for the following towns : Heyst, Dixmude, Ypres, as well as Tirlemont, Saint-Trond, Liége, Spa, Verviers, etc.

(3) This applies in particular to Ghent, Courtrai, Charleroi, etc.

TABLE 140.

TIME TAKEN BY ALL EXPRESS TRAINS BETWEEN CERTAIN PLACES.

(*Italics* = trains on the return journey).

RUN.	Set trains.	Other trains.	Average time taken in each direction.	Average time taken Total.	Best time.
			Minutes		
russels Midi-Ghent St. P.	8 × 34′ *8 × 33′*	3 × 34′ 9 × 40′ 2 × 42′ *33′ 36′ 2 × 38′ 2 × 39′* *40′ 11 × 41′ 42′*	37′ *37′*	37	33
russels Midi-Ostend	102′ 2 × 103′ *104′ 105′ 106′*	98′ 99′ 2 × 102′ 114′ *95′ 97′ 104′ 105′ 114′ 119′*	102′ *105′*	104	
russels Nord-Ghent St. P.	38′ *36′*	38′ 3×39′ 4×40′ 2×42′ 2×43′ 44′ *36′ 5×38′ 3×42′ 44′ 46′*	41′ *38′*	40	36
chaerbeek-Ghent St. P.	36′ 39′ *35′ 37′*	...	38 *36*	37	35
russels Nord-Ostend	... ...	85′ 88′ 90′ 91′ 95′ 2 × 109′ 110′ 2 × 111′ *87′ 90′ 102′ 2 × 106′ 4 × 109′* *111′ 118′ 120′*	100′ *106′*	103	76
russels Midi-Blankenberghe	93′ *98′*	94′ 110′ 2 × 112′ 131′ *110′ 2 × 119′ 120′ 2 × 121′*	109 *115′*	113	93
russels Nord-Blankenberghe	...	102′ 108′ *105′ 120′*	105 *113′*	109	102
russels Nord-Liége Guill.	6 × 75′ *6 × 72′*	8 × 75′ 78′ 102′ *6 × 72′ 76′ 100′*	78′ *74′*	75	72
(Antwerp) Louvain-Liége	3 × 53′ 54′ *2 × 50′ 51′*	...	53′ *52′*	52	50
(Ghent) Schaerbeek-Liége	2 × 72′ *2 × 69′*	...	72′ *69′*	71	69
russels Midi-Charleroi	5 × 44′ 48′ 49′ *5 × 44′ 47′*	44′ 2 × 49′ 51′ 52′ *48′ 51′ D*	47′ *46′*	46	44
russels Q.-L.-Charleroi	46′ 50′ *2 × 49′*	46′ *49′*	47′ *49′*	48	46
russels Q.-L.-Namur	...	51′ 4 × 52′ 53′ 56′ 2 × 59′ 60′ 63′ 64′ 65′ *2 × 52′ 2 × 53′ 2 × 54′* *2 × 56′ 57′ 58′ 59′ 60′* *62′ 63′ 66′*	57′ *57′*	57	51
russels Nord-Namur	...	53′ 61′ *52′ 61′*	57′ *57′*	57	52
russels Midi-Mons	2 × 51′ *56′*	2 × 41′ 2 × 43′ 52′ 57′ 58′ *3 × 46′ 49′ 53′ 54′ 57′*	50′ *51′*	51	41
russels Q.-L.-Mons	...	54′ *62′*	54′ *62*	58	54

Fig. 136. — Cartogram of Belgium showing places equidistant from Brussels from the point of view of the shortest time taken to reach them.

XXV-4. — **Interesting runs** (figs. 137 and 138). — The too frequent speed restrictions prevent us from getting a proper idea of the achievements of the express trains when only the overall speed is taken into account.

Here are some examples of the speed between given points of the journey for which the speed from start to finish is definitely lower.

BRUSSELS-LIÉGE. — On the outward journey, the express trains take 75 minutes; on the return run 72, with an

TABLE 141.

INTERESTING RUNS ON VARIOUS LINES OF THE SYSTEM.

RUN.	Distance		Time of departure.	Time spent.	Speed		
	Km.	Miles.			Km./h.	Miles/h.	
Brussels N.-Ostend Quay	117	73	R 7.44 p. m	1.16	92.4	57.4	« Nord Exp. », *winter.*
Do. M. do.	115	71	R 10.20 a. m.	1.14	93.3	58.0	
Do. N.-Alost-Ostend	120	75	...	...	...	...	
Brussels N.-Ghent St. P.	54	34	R 5.26 p. m.	0.36	90.3	56.1	Pullman express.
Do. M. do.	52	32	various	0.32	97.8	60.8	Set train, etc.
Ghent-Ostend Quay	64	40	3.11 p. m.	0.42	91.4	56.8	« Nord Express ».
Ghent-Bruges	41	25	5.34 p. m.	0.26	94.6	58.8	Set train.
Brussels-Ostend Town	23	14	R 8.12 a. m.	0.18	76.7	47.7	
Bruges-Ostend Quay	23	14	R 6.08 a. m.	0.18	76.7	47.7	
Schaerbeek-Ghent St. P.	53	33	R 6.22 p. m.	0.35	90.1	56.0	Set tr. Liége-Ghent.
Brussels N.-Bruges	96	60	...	...	...	...	
Do. M. do.	93	58	6.13 p. m.	0.58	96.4	59.9	Set train.
Brussels M.-Courtrai	85	53	R 5.29 p. m.	1.09	73.9	45.9	Set tr. fr. Poperinghe.
Brussels N.-Courtrai	87	54	R 7.48 a. m.	1.11	73.5	45.7	Set tr. from Roulers.
Antwerp C.-Malines-Ghent St. P.	72	45	R 5.29 p. m.	1.02	69.3	43.1	
Boom-Ghent St. P.	69	43	1.16 p. m.	1.11	58.3	36.2	
Ghent-Courtrai	42	26	5.18 p. m.	0.31	81.3	50.5	Set tr. Antw.-Lille.
Tête de Flandre-Ghent P. d'Anvers	51	31.6	7.19 p. m.	1.19	38.7	24.0	4 stops.
Brussels Midi-Dixmude	124	77	7.03 a. m.	1.36	79.4	49.3	To Adinkerke.
Brussels-Antwerp	...	...	...	...	...	...	See special table.
Antwerp-Esschen	31	19	7.31 a. m.	0.22	84.5	52.5	
Antwerp-Hamont	89	55	7.05 p. m.	1.26	62.1	38.6	2 stops.
Brussels N.-Liége-Verviers	125	78	1.33 p. m.	1.39	75.8	47.1	2 stops.
Brussels N.-Liége	100	62	6.52 a. m.	1.15	80.0	49.7	Set trains, etc.
			R 10.52 a. m.	1.12	83.4	51.8	Do.
Schaerbeek-Liége	97	60.3	R 5.06 p. m.	1.09	84.3	52.4	Set tr. Ghent-Liége.
Louvain-Liége	70	43	R 8.01 a. m.	0.50	84.0	52.2	Set tr. Antw.-Liége.
Brussels-St. Trond (Hasselt)	72	45	6.10 p. m.	0.54	80.0	49.7	Set tr. to Maeseyck.
Louvain-Antwerp Central	48	30	R 11.34 a. m.	0.39	73.8	45.9	
Louvain-Aerschot	16	10	R 8.07 a. m.	0.14	80.5	50.0	
Ghent-Malines	57	35	5.54 p. m.	0.41	82.0	50.9	Ostend Q.-Antwerp.
Malines-Louvain	25	15.5	R 9.10 a. m	0.19	78.9	49.0	
Brussels Nord-Luxemburg	226	140	R 1.21 p. m.	3.09	71.7	44.5	« Edelweiss », 1 stop.
Brussels Q.-L.-Arlon	191	119	R 12.28 p. m.	2.52	66.6	41.4	The Hague, 3 stops.
Brussels Nord-Namur	62	39	10.49 a. m.	0.52	71.5	44.4	« Edelweiss ».
Brussels Q.-L.- do.	56	35	11.30 a. m.	0.49	68.5	42.6	
Namur-Luxemburg	164	102	11.45 a. m.	2.15	72.9	45.3	« Edelweiss ».
Do. -Jemelle	57	35	R 1.36 p. m.	0.50	68.4	42.5	The Hague.
Jemelle-Arlon	79	49	R 12.28 p. m.	1.05	72.9	45.3	Do.
Brussels Midi-Charleroi	56	35	8.33 a. m.	0.44	76.4	47.5	Set train.
Brussels Q.-L.-Charleroi	58	36	7.38 a. m.	0.46	75.6	47.0	Set tr. from Antwerp.
Brussels Midi-Mons (Paris)	61	38	8.58 a. m	0.41	89.3	55.5	To Paris.
Brussels Midi-Aulnoye	95	59	R 10.17 p. m.	1.02	92.0	57.2	
Brussels Midi-Paris Nord	311	193	R 11.25 a. m.	3.11	97.7	60.8	To Luxemburg.
Brussels Nord-Tournai	90	56	9.00 a. m.	1.13	73.9	45.9	Pullman.
Brussels Q.-L.-Tournai	87	54	R *4.08* p. m.	*1.08*	*76.8*	*47.7*	*1932 summer.*
Tournai-Saint-André	29	18	10.14 a. m.	0.32	54.4	33.8	Pullman.
Saint-André-Calais Maritime	102	63	10.47 a. m.	1.07	93.4	58.0	Do.
Liége Guill.-Namur-Paris Nord	367	228	5.35 p. m.	3.50	95.7	59.5	*Nord-Belge Co.*
Liége Guill.-Namur	60	37	7.32 a. m.	0.42	85.7	53.3	*Do.*
Namur-Charleroi	37	23	8.15 a. m.	0.30	74.0	46.0	
Charleroi-Erquelinnes	30	19	9.00 a. m.	0.24	75.0	46.6	*Do.*

Fig. 137. — Cartogram of Belgium showing lines run over at various average speeds in 1914.

average speed of 80 and 83.4 km. (49.7 and 51.8 miles) an hour. Actually the 64 km. (39.76 miles) between Louvain and Ans are run over at the average speed of 91.4 km. (56.8 miles) an hour on the outward, and 103.8 km. (64.5 miles) an hour on the return journey (1).

BRUSSELS-LUXEMBURG. — The « Edelweiss » which runs through Jemelle at

(1) Four minutes are allowed from Brussels to Schaerbeek (45 km. = 28 miles an hour), and 27 minutes from there to Louvain (85.3 km. = 53 miles an hour).

The gradient from Ans to Liége is run down in 10 minutes (36 km. = 22.4 miles an hour), and up in 12 (30 km. = 18.6 miles an hour).

Fig. 138. — Cartogram of Belgium showing lines run over at various average speeds in **1934**.

12.32 and Arlon at 1.35 p.m. takes 2 hours 50 minutes between Namur and Arlon, and consequently covers this stage of the journey at a speed of 74.2 km. (46.1 miles) an hour.

IN OTHER COUNTRIES. — Belgian locomotives haul certain trains outside the Belgian frontier.

In the north they go as far as Roosendaal, the first stop after Antwerp Est. The distance from the frontier to Roosendaal is 9 km. (5.6 miles).

In the east they run to Aix-la-Chapelle. The distance from Herbesthal to Hergenrath is 8 km. (5 miles), to which must be added the 8 km. on to Aix-la-Chapelle.

In the south-east, Belgian locomotives run as far as Luxemburg, which is 18 km. (11.2 miles) beyond the frontier. The timings are relatively slow in the Grand Duchy, both in the case of the line from Belgium and that towards Alsace on which French locomotives work.

On the other hand, locomotives belonging to the *Nord* haul the non-stop trains from Paris to Brussels. In spite of what has been said — and has been frequently repeated — there is no slowing down at the frontier, but the line is much more difficult in Belgium than in France. To be just, one should consider the average speed of the trains not only from Paris to the frontier (on the *Nord* alone) but also to the frontier of that system at Mons, this section belonging to its subsidiary, the *Nord Belge*, and then on to Brussels Midi, which is the end of the non-stop run.

SPEED OF NON-STOP TRAINS FROM PARIS TO BRUSSELS
over various sections of the run.

RUN.	Company.	Distance		Time spent.	Speed.	
		Km.	Miles.		Km./h.	Miles/h.
Paris Nord to Quévy	Nord (French lines).	235	146	2.19	101.5	63.1
Quévy to Mons	Nord (Belgian lines).	15	9.3	0.11	81.8	50.8
Paris Nord to Mons	Nord (French + Belg.).	250	155	2.30	100.0	62.0
Do. to Brussels Midi .	Nord (French + Belg.). and Belgian Nat. Rys. Co.	311	193	3.11	97.7	60.7

Between Aulnoye and Brussels, the timetable of the through express trains hauled by French locomotives is, although the trains are often lighter, a minute slower than the night express which stops at Aulnoye, in which case a Belgian locomotive covers 34 km. (21.1 miles) on foreign territory.

XXV-5. — **Fast runs.** — We have included in table 142 the run from Saint-André to Calais Harbour, made at the average speed of 93.4 km. (58 miles) an hour by Belgian locomotives, which cover the distance between Brussels and Tournai at the average speed of 74 km. (46 miles) an hour only (1).

The run from Brussels to Aulnoye is a mixed run, 34 km. (21.1 miles) being over the French *Nord* system where there are gradients of 1 in 100 and over.

XXV-6. — **Long non-stop runs.** — In order to get hold of the Anglo-German traffic, the lines from Flushing and Ostend to Cologne competed very strenuously against each other before the war, and the *Belgian State Railways*, to win the fight, introduced trains from Ostend to Cologne via Malines instead of Brussels in order to avoid the inevitable slowing down round the capital. One of these trains, intended especially for carrying the mails and parcels traffic made the journey from Ostend to Verviers in 3 hours 35 minutes, with only

(1) 76.8 km. (47.7 miles) an hour in 1932.

TABLE 142.

THE FASTEST TRAINS.

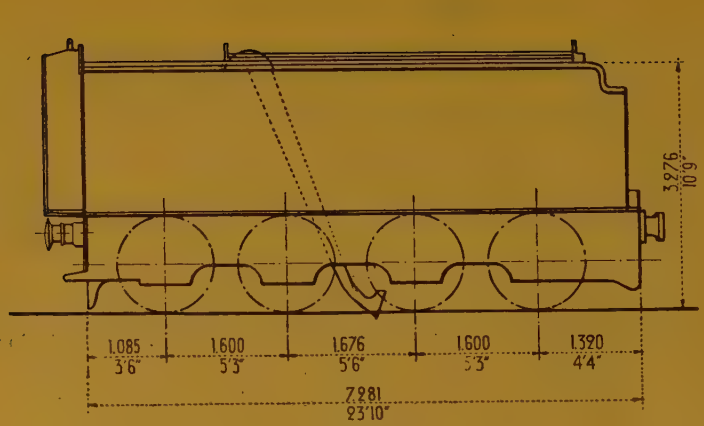
RUN.	Distance		Time of departure.	Time spent.	Speed		
	Km.	Miles.			Km./h.	Miles/h.	
Brussels Midi-Ghent St. P.	52	32	various.	0.33	97.8	60.8	Set trains.
Brussels Midi-Bruges	93	58	6.13 p. m.	0.58	96.4	59.9	To Ostend.
Ghent St. P.-Bruges	41	25	5.34 p. m.	0.26	94.6	58.8	Do.
Saint-André-Calais Mar.	102	63	10.47 a. m.	1.07	93.4	58.0	Pullman express.
Brussels Midi-Ostend Quay	115	71	R. 10.20 a. m.	1.14	93.3	57.9	In winter.
Brussels Nord-Ostend Quay	117	78	R. 7.44 p. m.	1.16	92.4	57.4	« Nord Express ».
Brussels Midi-Aulnoye	95	59	R. 10.17 p. m.	1.02	92.0	57.2	Brussels-Paris.
Ghent St. P.-Ostend Quay	64	40	3.11 p. m.	0.42	91.4	56.8	« Nord Express ».
Antwerp C.-Lierre-Louvain	46	29	R. 2.48 p. m.	0.39	70.9	44.1	From Liége.
Ghent St. P.-Schaerbeek	53	33	6.22 p. m.	0.35	90.1	55.9	Set train to Liége.
Liége Guillemins-Namur	60	37	7.32 a. m.	0.42	85.7	53.2	Nord-Belge lines.
Schaerbeek-Liége Guillemins	97	60	R. 5.06 p. m.	1.09	84.3	52.4	Set train from Ghent.
Antwerp Est-Esschen	31	19.3	8.44 a. m.	0.22	84.5	52.5	Basle-The Hague.
Brussels Nord-Liége Guillemins	100	62	R. 10.52 a. m.	1.12	83.4	51.8	Set trains, etc.
Ghent St. P.-Courtrai	82	60	5.28 p. m.	0.31	81.3	50.5	Set tr. from Antwerp.

one stop for water at Louvain. It was not run again after the armistice.

It is true that, the trains having been speeded up, the same journey, but via Brussels Nord this time, can be made in 3 hours 14 minutes by the Pullman trains and 3 hours 29 minutes by the ordinary express trains, in spite of three stops in the first case and 5 in the second, which take 18 minutes and 22 minutes respectively. On the return journey these same trains pass Verviers non stop.

When first introduced, the Pullman trains did not stop between Brussels and the frontier (except at Liége), but, as always happens, additional stops have since been arranged. The trains from Ostend stop at Ghent; the « Edelweiss » which ran non-stop between Brussels and Luxemburg, stops at Namur, while the Pullman from Calais stops at Tournai.

The long non-stop runs are possible thanks to the larger 38.3 m³ (8 430 Br. gallons) tenders of the Belgian National Railways Company, which are the largest in Europe. For comparison, we have given in figure 139 diagrams of the large tenders of the *Nord* and *Est* (France), of the *Reichsbahn* (Germany), and the tenders of the *L.N.E.R.* which scoop up water while running. In spite of this, their water capacity is much less than that of the American tenders, as will be seen from the drawings of tenders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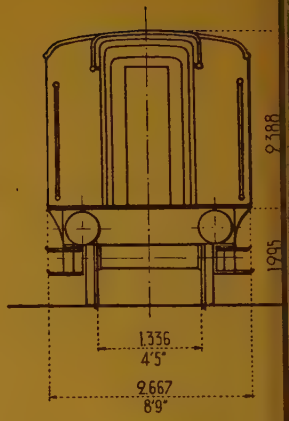
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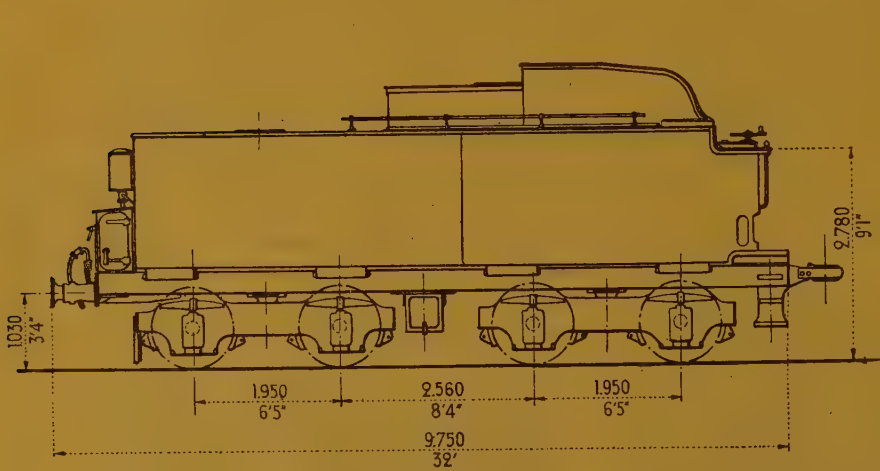
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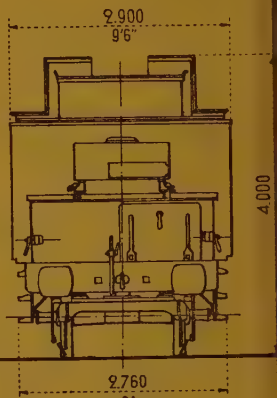
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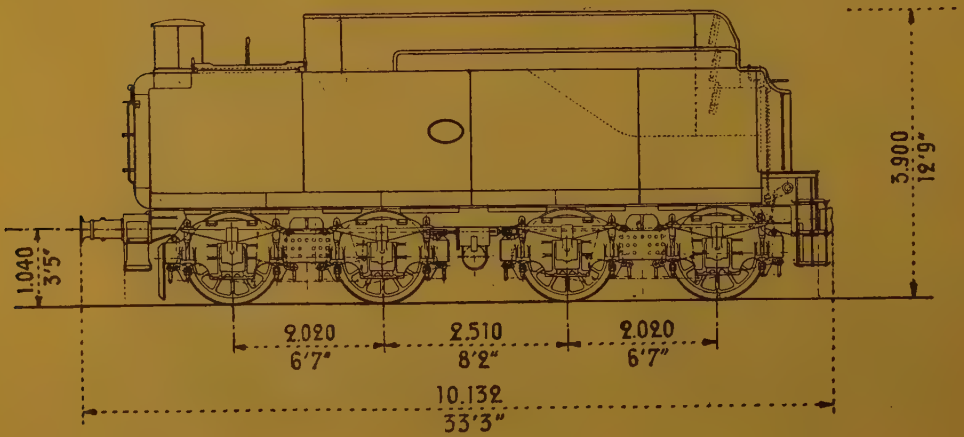
9'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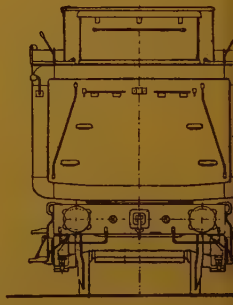


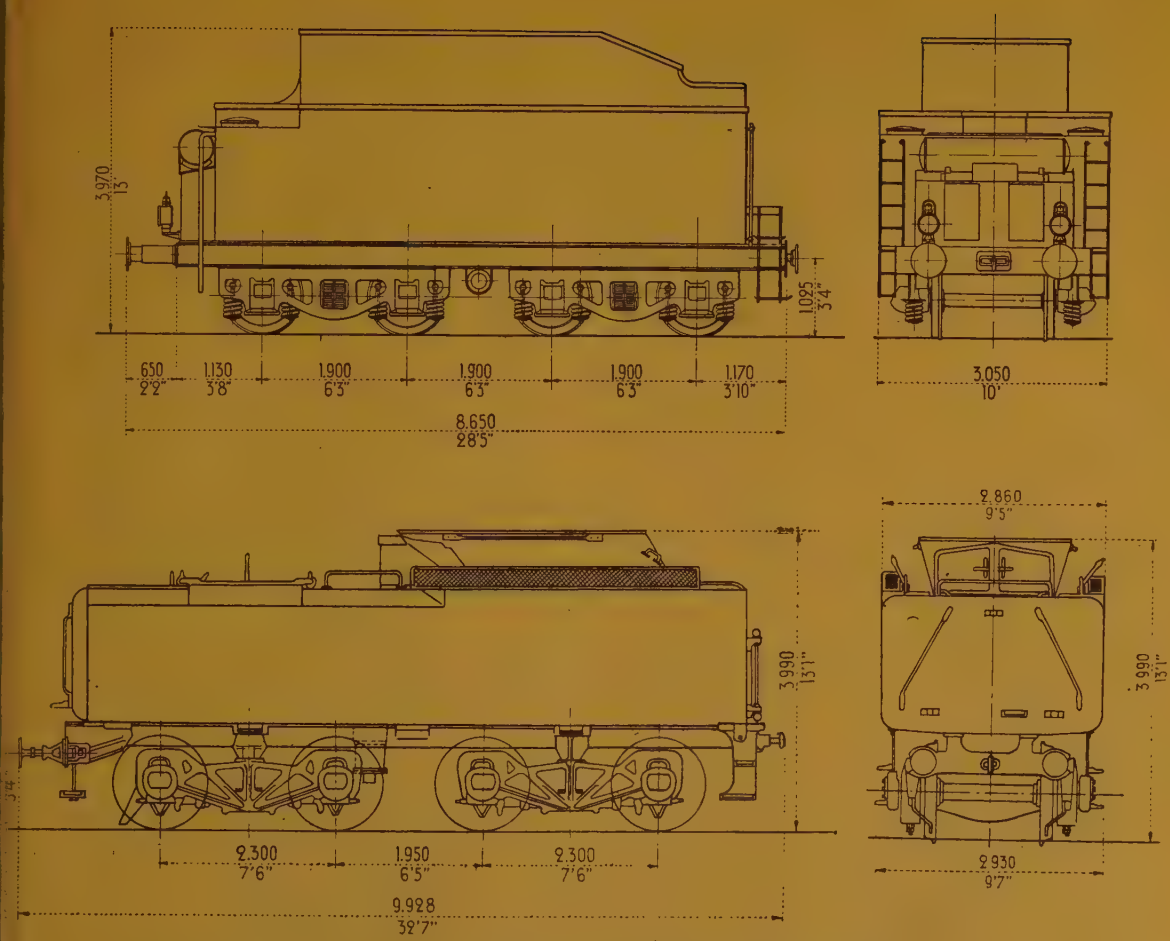


Fig. 139. — Examples of large tenders.

LEFT-HAND PAGE.

a) England. — Corridor tender of the London & North Eastern Railway.
b) Germany. — Reichsbahn.
c) Belgium. — Belgian National Railways Company.

RIGHT-HAND PAGE (above).

d) France. — Est Railway.
e) France. — Nord Railway. — Tender with large-diameter wheels.

of various dimensions which the *Pennsylvania* Railroad attaches to its *Pacific* engines (1) (fig. 140).

TABLE 143.

LONGEST NON-STOP RUNS.

RUN.	Distance Km.	Distance Miles.	Time of departure.	Time spent.	Speed. Km./h.	Speed. Miles/h.	
BELGIAN RUNS.							
Ostend Quay-Malines-Verviers	240	149	*3.25* a. m.	*3 25*	*70 2*	*43.6*	*To Cologne.*
Brussels Q.-L.-Luxemburg	219	136	..	...	...	...	« *Edelweiss* ».
Namur-Luxemburg	164	102	11.45 a. m.	2.15	72 9	45.3	Do.
Brussels Midi-Dixmude	124	77	7.03 a. m.	1.36	79.4	49.3	To Adinkerke.
Brussels Nord-Ostend Quay	117	72.7	R 7.44 p. m.	1.16	92.4	57.4	« Nord Express ».
Brussels Midi-Ostend Quay	115	71.5	R 10.20 a. m.	1.14	93.3	58.0	In winter.
Brussels Nord-Liége Guill.	100	62	R 10.52 a. m.	1.12	83.4	51.8	Set train, etc.
Schaerbeek-Liége Guill.	97	60.3	R 5.06 p. m.	1.09	84.3	52.4	Set tr. from Ghent.
Brussels Midi-Bruges	93	57.8	6.13 p. m.	0.58	96.4	59.9	To Ostend.
Brussels Nord-Courtrai	87	54	R 7.48 a. m.	1.11	73.5	45.7	Set train.
Brussels Midi-Courtrai	85	52.8	R 5.29 p. m.	1.09	73.9	45.9	Set tr. Poperinghe.
Arlon-Jemelle	79	49	12.28 p. m.	1.05	72.9	45.3	To The Hague.
(Pass.) Quévy-Brussels Midi	76	47	pass. 1.44 p. m.	0.52	87.7	54.5	
Brussels Nord-Saint-Trond	72	45	6.10 p. m.	0.54	80.0	49.7	Set train Maeseyck.
Liége Guill.-Louvain	70	43.5	8.01 a. m.	0.50	84.0	52.2	Set tr. from Antwerp
FRANCO-BELGIAN RUNS.							
Liége Guill.-Paris Nord	367	228	5.35 p. m.	3.50	95.7	59.4	
Brussels Midi-Paris Nord	311	193	R 11.25 a. m.	3.11	97.7	60.7	« Etoile du Nord ».

XXV-7. — **Provincial centres.** — Antwerp, Ghent, Liége (figs. 141 to 144) and Charleroi are the most important of these. Antwerp is, in addition, closely linked up with Brussels, as has been explained previously.

Each of the two Antwerp terminal stations (Central and Sud) as well as its

(1) The leading dimensions are as follows :

	Pacific.	
Type		
Cylinders, diameter	0.685 m.	27 inches.
Do. stroke	0.760 m.	28 inches.
Wheels, diameter	2.032 m.	80 inches.
Height	4.72 m.	15 ft. 6 in.
Weight empty	156.0 t.	278 700 lb.
Weight in working order	176.9 t.	313 000 lb.

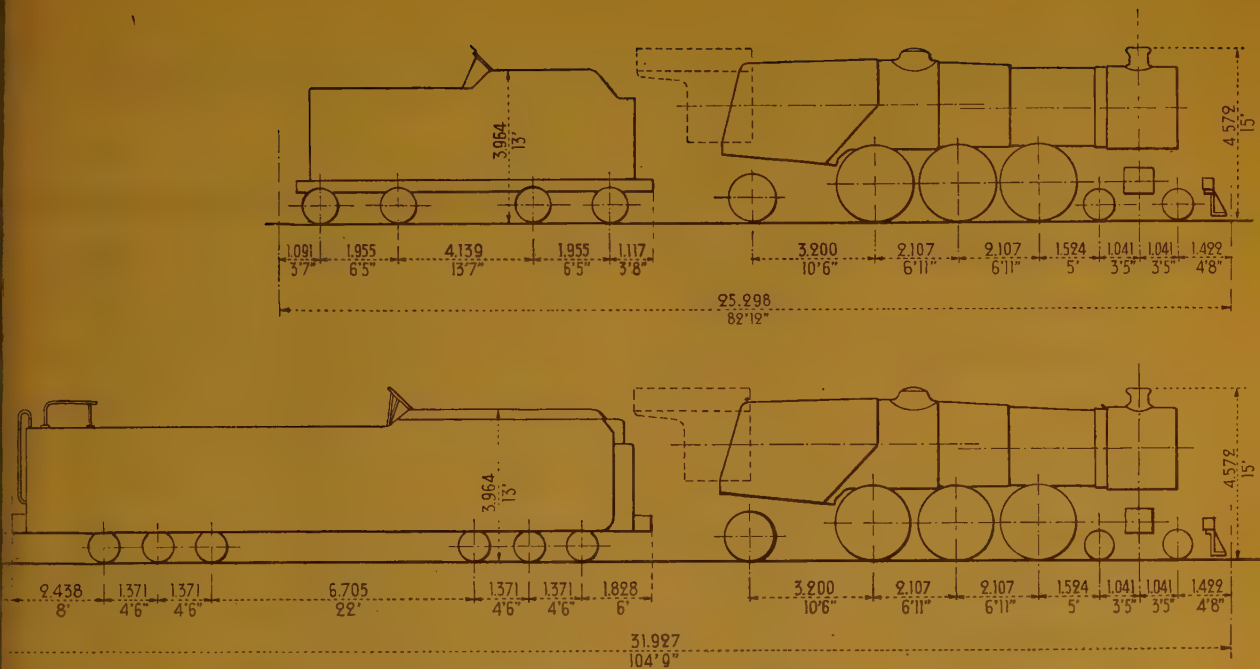


Fig. 140. — Pennsylvania Railroad tenders.

Fig 141. — Chart showing the best speeds maintained by non-stop trains serving : *a*) Brussels. — *b*) Liége.

TABL

LEADING DIMENSIONS OF SOM

COMPANY.	Belgian National Railways Co.	Nord.	Est.
Water capacity . . . . . m³ (*Br. gall.*).	38.300 (8 430)	37.000 (8 140)	35.641 (7 840)
Coal capacity . . . . . M. t. (*Engl. t.*).	10 (9.8)	9 (8.9)	7 (6.9)
Length, overall . . . . . m. (*ft. in.*).	9.350 (30 ft. 8 in.)	3.928 (32 ft. 7 in.)	9.750 (32 ft.)
Width do. . . . . m. (*ft. in.*).	2.860 (9 ft. 4 5/8 in.)	2 860 (9 ft. 4 5/8 in.)	2.900 (9 ft. 6 3/16 in.)
Height do. . . . . m. (*ft. in.*).	3.920 (12 ft. 10 11/32 in.)	3.990 (13 ft. 1 in.)	4.000 (13 ft. 1 1/2 in.)
Number of wheels	8	8	8
Wheel diameter . . . . . m. (*ft. in.*).	1.250 (4 ft. 1 3/16 in.)	1.248 (4 ft. 1 1/16 in.)	1.080 (3 ft. 6 1/2 in.)
Bogie wheel base . . . . . m. (*ft. in.*).	2.020 (6 ft. 7 1/2 in.)	2.300 (7 ft. 6 1/2 in.)	1.950 (6 ft. 4 13/16 in.)
Between bogie centres. . . . m. (*ft. in.*).	4.350 (14 ft. 3 9/32 in.)	4.250 (13 ft. 11 5/16 in.	4.510 (14 ft. 9 9/16 in.)
Weight, empty . . . . . M. t. (*Engl. t.*).	34.220 (33.7)	30.500 (30.0)	29.744 (29.3)
Do. in working order . M. t. (*Engl. t.*).	82.520 (81.2)	76.900 (75.7)	72.940 (71.8)

through international station (Est, replacing Berchem) are connected by through non-stop trains to the two termini (Nord and Midi) and the through (Q. L.) station, of Brussels.

TABLE 145.

BRUSSELS AND ANTWERP TRAIN SERVICE.

FROM BRUSSELS.	To ANTWERP.	Distance Km.	Distance Miles.	Time of departure.	Time spent.	Speed Km./h	Speed Miles/h.	
Nord	Central.	44	27.3	9.20 a. m.	0.35	75.4	46.9	Set train.
Do.	Est.	43	26.7	8.00 a. m.	0.38	67.9	42.2	Brussels-Amsterdam.
Do.	Sud.	44	27.3	5.48 p. m.	0.43	61.4	38.2	Boat train.
Midi	Central.	50	31.1	R 8.51 a. m.	0.45	66.7	41.4	Paris-Antwerp.
Do.	Est.	49	30.4	2.50 p. m.	0.46	63.9	39.7	Paris-Amsterdam.
Quartier-Léopold . . .	Central.	48	29.8	6.28 p. m.	0.39	76.4	47.5	Set tr. from Charleroi
Do. . . .	Est.	47	29.2	3.43 p. m.	0.44	64.1	39.8	« Edelweiss ».

The time taken by the express trains between Brussels Nord and Antwerp Central was 34 minutes before the war, over a line with heavy traffic where the

CENT LARGE TENDERS.

Reichsbahn.	L. & N. E.	Pennsylvania Railroad.		
32.000 (7 040)	22.720 (50 00)	46.000 (10 120)	83.650 (18 400)	92.436 (20 335)
10 (9.8)	9 (8.9)	16.3 (16.0)	28.6 (28.2)	22.7 (22.3)
8.650 28 ft. 4 1/2 in.)	7.420 (24 ft. 4 in.)	9.785 (25 ft. 6 1/2 in.)	15.494 (50 ft. 10 in.)	16.450 (53 ft. 11 11/16 in.)
3.050 (10 ft.)	2.667 (8 ft. 9 in.)	...	...	...
3.970 13 ft. 5/16 in.)	2.388 (7 ft. 10 in.)	3.965 (13 ft.)	3.965 (13 ft.)	3.965 (13 ft.)
8	8	8	12	12
1.000 3 ft. 3 3/8 in.)	1.270 (4 ft. 2 in.)	0.914 (3 ft.)	2.039 (6 ft. 8 9/32 in.)	0.839 (2 ft. 9 in.)
1.900 ft. 2 13/16 in.)	1.600 (5 ft. 3 in.)	1.883 (6 ft. 2 in.)	2.743 (9 ft.)	2.743 (9 ft.)
3.800 12 ft. 5 5/8 in.)	3.276 (10 ft. 9 in.)	6.10 (20 ft.)	9.778 (32 ft. 1 in.)	9.449 (31 ft.)
...	30.850 (30.4)	32.432 (31.9)	46.766 (46.0)	64.500 (63.5)
...	63.130 (62.2)	96.500 (95.0)	171.447 (168.7)	173.600 (170.8)

speed was very limited over the Malines swing bridge and through its station. Last winter the time taken was 35 minutes in spite of a detour of 1 400 m. (0.87 mile) via Mortsel owing to work in hand to quadruple the line, raise and electrify it. When all this work is completed it is hoped to take 28 minutes only, 4 minutes improvement on pre-war timings.

As an additional five minutes has been temporarily added to the times of all the trains between Brussels and Antwerp, we give in table 145 the figures relating to the 1933/34 winter.

Trains starting both from Antwerp, and from Brussels run over all the Belgian main lines :

MAIN LINES.

West	To Ostend, to Blankenberghe and to Knocke.
East-additional	To Hamont and M./Gladbach.
East	To Liége and Cologne, and also to Spa.
South-east	To Luxemburg and Basle.
Intermediate	To Charleroi.
South	To Brussels and Paris.
Intermediate	To Courtrai-Lille and to Adinkerke.

In order to link up with the great east to west line, at Louvain and at Termonde (Ghent), there are in each case alternative routes. This is one of the

few examples of such lines in Belgium. Their length by the different routes is as follows (1) :

	Km.	Miles.
Antwerp Central-Malines (Neckerspoel)-Louvain . .	46.575	28.95
Do. -Malines-Louvain	54.025	33.55
Do. -Lierre-Aerschot-Louvain	57.967	36.00
Do. -Malines-Termonde-Ghent St. P. . . .	80	49.71
Antwerp S.-Boom-Termonde-Ghent St. P.	69	42.87
Antwerp (Tête de Flandre) (2)-Lokeren-Ghent St. P. .	58	36.04

There are no through trains from Antwerp to Lille via Brussels [165 km. (102.5 miles) by the west circle and 161 km. (100 miles) by the Q. L.], because the line from Antwerp to Lille via Ghent is more direct (153 km. = 95.1 miles) and easier (3).

Except for the last named, all these lines have expresses. That from Tête de Flandre is a local line, the length of which up to Ghent Porte d'Anvers station is only 53 km. (32.9 miles). It was built by the *Compagnie du Pays de Waes* with 1.151-m. (3 ft. 9 9/32 in.) gauge track between the centres of the rails (1.10 m. = 3 ft. 7 5/16 in. between the flanges), and was a prototype of the narrow gauge lines and metre lines built since then. In addition to the possibility of getting an excellent output from a line only two thirds the width of standard gauge lines, Mr. Deridder, the inventor, introduced on it a series of innovations, which made it one of the most interesting lines of the time (4). It was relaid to the standard gauge when the State took it over.

From Antwerp to Charleroi there are

(1) Antwerp E.-Lierre . . . . . 13.106 km. (8.14 miles).
Do. S.-Lierre . . . . . 16.928 km. (10.51 miles).
Do. C.-Lierre . . . . . 13.934 km. (8.64 miles).
Antwerp C.-Malines . . . . . 23.170 km. (14.40 miles).
Do. S.-Malines . . . . . 21.975 km. (13.66 miles).
Do. S.-Neckerspoel . . . . . 22.626 km. (14.05 miles).

(2) There is no railway connection between the stations on the two banks of the Scheldt, which are however linked up by road tunnels. The length of the tunnel for road vehicles is 1 768.85 (1 934 yards), 395 m. (432 yards) of which are under the river.

(3) Antwerp Central-Boom-Ghent-Courtrai, 112.04 km. (69.6 miles).

(4) This was the first Belgian railway that was not operated by the State. The concession was granted in 1844; it was operated as far as St. Nicolas (18 km. = 11.2 miles) in that year, and Deridder only formed it into a company the next year. The line was completed in 1847, and its construction price of 90 000 fr. (gold) the kilometre had not exceeded the estimates.

The gauge of 1.10 m. between the flanges corresponds to 1.151 m. between centres. In spite of its immediate success, in 1870 it was still the only metric railway in the world.

Its 50 km. (31 miles) were divided into 7 straight stretches connected by large-radius curves, the smallest of which was 840 m. (42 chains). The gradients did not exceed 1 in 285. There was only one lifting bridge, that over the river Durme.

The ends of the 22-kgr. (44 lb. per yard) rails were scarfed.

4-4-4 saddle tank type locomotives with 1.44 m. (4 ft. 8 1/2 in.) wheels, and the cylinders between the 2nd and 3rd pairs of wheels, were used. They burnt run-of-mine coal until 1853, and then briquettes.

The floor of the vehicles was 0.80 m. (2 ft. 7 1/2 in.) above the rails, their wheels were 1.10 m. (3 ft. 7 5/16 in.) in diameter, and they were coupled by an iron draw bar, and buffing and draw springs.

The only other Belgian lines built to others than the standard gauge were the local railway from Noville-Taviers to Embresin [10 km. = 6.2 miles with 0.717 m. (2 ft. 4 1/4 in.) gauge] and the local railways in the north of the Antwerp district, built to 1.067 m. (3 ft. 6 in.) gauge, so as to be able to connect up with the Dutch railways. At the present time these local railways have metre-gauge lines.

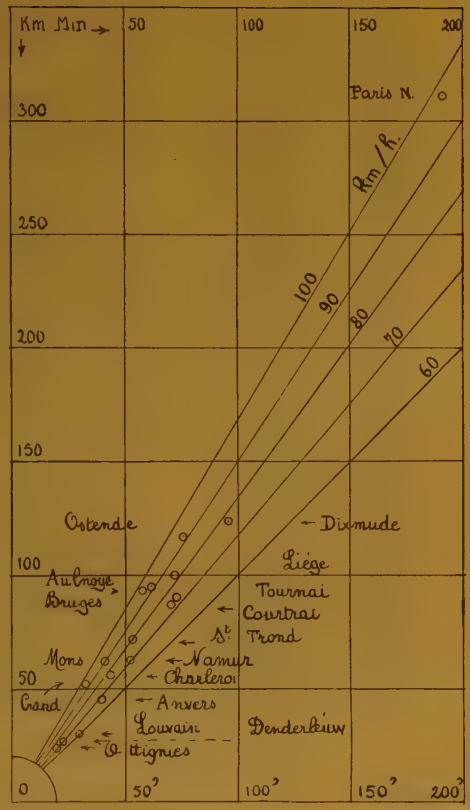


Fig. 142. — Chart of non-stop runs and the speeds attained (BRUSSELS).

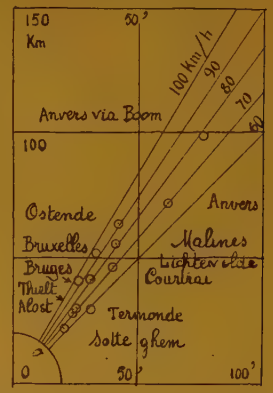
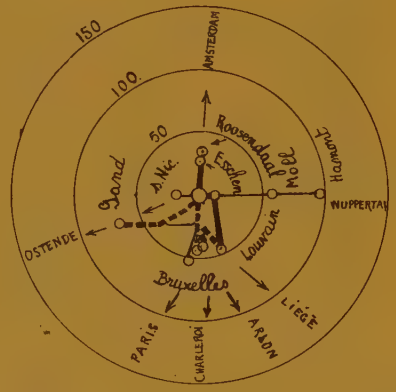


Fig. 143. — Chart showing the best speeds of non-stop trains serving GHENT.



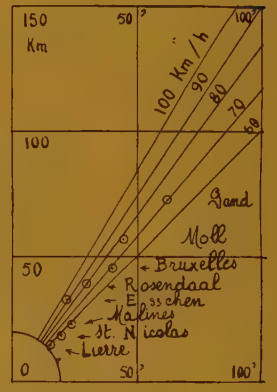


Fig. 144. — Chart of the best speeds of non-stop trains serving ANTWERP.

Table 146.

ARTICULATED LOCOMOTIVES USED IN BELGIUM.

COMPANY. LOCOMOTIVE TYPE.	Grand Luxembourg 0 — 6 — 0 Steam tender 1866.	Grand Central Belge 0 — 6 — 0 Steam tender 1867.	Grand Central Belge 0 — 6 + 6 — 0 Meyer 1872.	State 0 — 6 + 6 — 0 Mallet 1897.	Light Railways 0 — 6 + 6 — 0 Garratt 1930.
Cylinders, bore . . . . m. *(in.)*.	0.42 (16 1/2″)	0.46 (18 1/8″)	0.44 (17 5/16″)	0.40—0.58 (15 3/4″ — 22 13/16″)	0.36 (14 3/16″)
Do. stroke . . . m. *(in.)*.	0.60 (23 5/8″)	0.60 (23 5/8″)	0.60 (23 5/8″)	0.64 (25 1/4″)	0.35 (13 3/4″)
Heating surface . . . m^2 *(sq. ft.)*.	132 (1421)	179 (1 927)	125 (1 345)	154 (1 658)	83 + 20 893 + 215 spht.
Boiler pressure . . . kgr./cm^2 *(lb./sq. in.)*.	10 (142)	9 (128)	9 (128)	12 (171)	14 (199)
Wheel diameter . . . m. *(ft. in.)*.	1.50 (4 ft. 11 in.)	1.22 (4 ft.)	1.22 (4 ft.)	1.23 (4 ft. 7/16 in.)	0.85 (2 ft. 9 1/2 in.)
Weight in service . . . Metr. t. *(Engl. t.)*.	33 (32.5)	36 (35.4)	72 (*) (70.9)	85 (83.6)	58 (57.1)
STEAM TENDER.					
Type	0 — 6 — 0	0 — 6 — 0	...	...	...
Cylinders, bore . . . . m. *(in.)*.	0.38 (14 15/16″)	0.35 (13 3/4″)	...	...	...
Do. stroke . . . m. *(in.)*.	0.42 (16 1/2″)	0.40 (15 3/4″)	...	...	...
Wheel diameter . . . m. *(ft. in.)*.	1.20 (3 ft. 11 1/4 in.)	1.22 (4 ft.)	...	...	...
Weight in service . . . Metr. t. *(Engl. t.)*.	28 (27.5)	27 (26.5)	...	...	...
Do. empty . . . . Metr. t. *(Engl. t.)*.	16 (15.7)	15 (14.8)	...	...	...

(*) This locomotive was the most powerful that had been built up to that time (72 tons instead of 50). (See fig. 146.)

also two routes : the first via Louvain belongs to the former *Grand Central Belge* Railway, and the other, via Brussels, has been much shortened since the Watermael-Linkebeek (towards Hal) junction was made.

	Km.	Miles.
Antwerp Central-Louvain-Charleroi Ouest	120	75
Do. Sud -Louvain-Charleroi Ouest	123	76
Antwerp-Central-Brussels Nord, Midi-Charleroi Sud	117	73
Do. -Brussels Q.-L.-Charleroi Sud	106	65

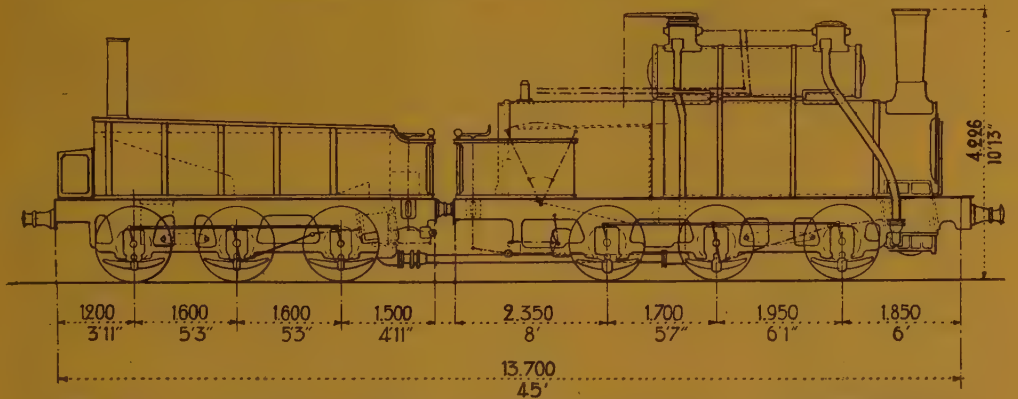


Fig. 145. — Locomotive with steam tender, of the former *Grand Luxembourg* Railway.

It may be mentioned by the way that in order to improve its services, which were in competition with those of the Belgian State Railways, the *Grand Central* experimented with locomotives with steam tenders (1) (fig. 145), the prototype of the Sturrock type locomotives of the *Great Northern Railway*, and afterwards with a large Meyer (2) locomotive (fig. 146).

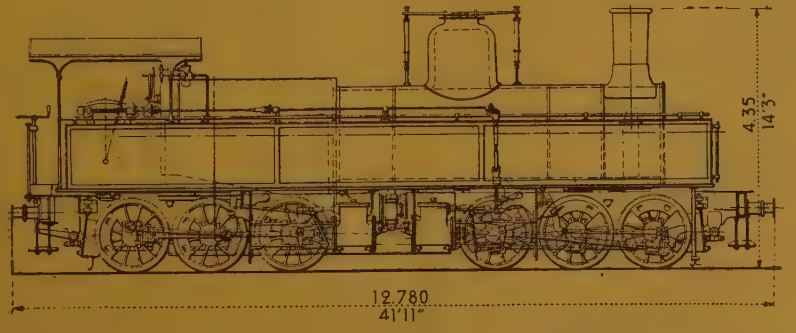


Fig. 146. — Meyer locomotive of the former *Grand Central Belge* Railway.

(1) This locomotive, used for the Lodelinsart 1 in 55 gradient, hauled 250 to 300-ton trains at 20 km. (12.4 miles) an hour. It was similar to that used by the *French Est* Railway in 1866 on the *Grand-Luxembourg*, which it operated.

(2) At that time, this was the most powerful locomotive in Europe. We have given above the leading dimensions, as well as those of other articulated locomotives, used for experimental purposes in Belgium.

TABLE 147.

AVERAGE SPEEDS OF THE FASTEST EUROPEAN ELECTRIC TRAINS.

RUN.	Distance		Time spent.	Speed.	
	Km.	Miles.		Km./h.	Miles/h.
FRANCE.					
Paris Austerlitz-Vierzon	204	126.8	2.14	91.3	56.7
Do. -Les Aubrais	123	76.4	1.16	97.1	60.3
Les Aubrais-St.-Pierre-des-Corps	112	67.6	1.02	108.2	67.1
St.-Pierre-des-Corps-Poitiers	101	62.7	1.02	97.7	60.7
Bordeaux-Lamothe	40	24.9	0.30	80.0	49.7
Lamothe-Dax	108	67.1	1.09	93.9	58.3
ITALY.					
Bologna-Florence	98	60 9	1.06	89.1	55.3
Milan P. N.-Varese	59	36.7	0.41	86.3	53.6
Viareggio-La Spezia	54	33.6	0.40	81.0	50.3
Pisa-La Spezia	75	46.6	1.02	72.6	45.1
Turin-Asti (Genoa)	56	34.8	0.42	80.0	49.7
Naples-Villa Literno	30	18.6	0.23	78.3	48.7
GERMANY.					
Munich-Augsburg	62	38.5	0.43	86.5	53.7
Augsburg-Ulm	85	52.8	0.59	86.4	53.6
Ulm-Stuttgart	93	57.8	1.11	78.3	48.7
Munich-Landshut	75	46.6	0.53	84.8	52.7
Landshut-Regensburg	62	38.5	0.50	74.4	46.2
Munich-Freilassing (Salzburg)	149	92.5	1.45	85.2	52.9
Munich-Stuttgart	240	149.1	2.51	84.2	52.3
SWITZERLAND (1).					
Geneva-Lausanne	60	37.3	0.45	80.0	49.7
Brig-Sion (Lausanne)	53	32.9	0.41	77.6	48.2
Sion-Montreux (Lausanne)	68	42.3	0.54	75.6	48.2
Frauenfeld-Weinfelden	17	10.6	0.13	78.5	48.8
Basle-Zurich (HB)	88	54.7	1.11	74.3	46.2
Berne-Thun (Lötschberg)	31	19.3	0.25	74.4	46.2
NETHERLANDS.					
Amsterdam-Haarlem	19	11.8	0.14	81.5	50.7
Haarlem-Leiden	29	18.0	0.20	87.4	54.3
Leiden-The Hague	15	9.3	0.11	81 8	50.8
Amsterdam-Uitgeest (Alkmaar)	23	14.3	0.17	81.2	50.4
ENGLAND.					
Victoria-Brighton	82	51.0	1.00	81.8	50.8
HUNGARY.					
Budapest (Kelenföld)-Györ	130	80.8	1.44	75.0	46.6
AUSTRIA (1).					
(Salzburg) Wörgl-Jenbach	82	51.0	1.08	72.2	44.8
(Vienna F.J.) Heiligenstadt-Krems	73	45.4	1.01	71.8	44.6

(1) In the case of these countries, we have given the actual distances worked and not the rating distances quoted in the timetables This explains the difference in mileage found in some cases.

Speed of electric trains. — The Brussels-Antwerp line is the first electrified line in Belgium over which express trains will run, so that it is interesting to compare the speeds of the fastest electric trains in Europe.

France leads in this respect (*Paris-Orleans* system) with 108.2 km. (67.2 miles) an hour for the « Sud Express », but it is a striking fact that the section over which this train reaches its highest average speed is that of Poitiers to Angoulême, a non-electrified one where the steam locomotives maintain an average speed of 113 km. (70.2 miles) an hour.

XXV-8. — **Conclusions.** — We have got out the mileage of the railway system run over at the various speeds we took as our bases, and below we give a summary of these :

TABLE 148.

DEVELOPMENT OF THE BELGIAN RAILWAY SYSTEM AND THE VARIOUS OVERALL SPEEDS FOUND THEREON.

Belgian Nat. Rys.	Nord.	COMPANY.		Belgian Nat. Rys.		Nord.	
				Km.	%	Km.	%
		(Miles).	*(Kilometres).*				
...	...	Over 62	Over 100	...	...	...	...
58	...	59 to 61.9	95 to 99.9	93	1.8	...	...
126	9	56 to 58.9	90 to 94.9	202	4.1	15	9
115	56	50 to 55.9	80 to 89.9	184	3.8	90	53
463	...	44 to 49.9	70 to 79.9	745	15.5	...	...
433	...	38 to 43.9	60 to 69.9	697	14.3	...	...
1 827	40	Under 38	Under 60	2 940	60 5	65	38
3 021	105	← TOTAL →		4 861	100	170	100

For purposes of comparison the same table for the services of 20 years ago (summer 1914) is reproduced below. The progress made is considerable.

Belgian Nat. Rys.	Nord.	COMPANY.		Belgian Nat. Rys.		Nord.	
				Km.	%	Km.	%
		(Miles).	*(Kilometres).*				
...	...	Over 56	Over 90	...	...	...	...
75	...	50 to 55.9	80 to 89.9	122	2.8	...	...
165	56	44 to 49.9	70 to 79.9	265	6.2	90	53
363	9	38 to 43.9	60 to 69.9	585	13.5	15	9
2 087	40	Under 38	Under 60	3 358	77.5	65	38
2 691	105	← TOTAL →		4 330	100	170	100

In 1914 many trains were timed at a speed of 60 km. (37.30 miles) an hour, increased by one minute — so they could not be included in the above table.

(To be continued.)

[625. 113]

The angles diagram method applied to repegging existing curves and to new lines with long transition curves,

by Dr.-Ing. GERHARD SCHRAMM, Reichsbahnrat, Augsburg.

A. General considerations.

B. Theory.

C. Example : pegging out a curve.

D. Pegging out, starting from any polygonal layout.

E. Pegging out new railway lines with long transition curves.

A. — General considerations.

The former methods of pegging out curves started from the different tangents and involved trigonometrical calculations. This method has several drawbacks, such as : it is not too accurate; the calculations are laborious; the work is difficult in tunnels, on high embankments, in deep cuts, on bridges, etc...; it takes much time, etc. Recently other methods have been introduced based on the use of an existing curve or a many-sided polygonal layout as the base line, that is to say the curve is pegged out starting from this line, without any trigonometrical calculation being needed. The first thing done is to measure the versines of the curve in question, and from these measurements deduct the distances of the new curve from the old. There are two methods of doing this; the first by calculation (1), and the second by graphs (2).

The particular characteristic of this second method, which uses a track curve as its base line, lies in the fact that the measured ordinates are

(1) Cf. CHAPPELET : The systematic adjustment of curve pegging by the correction of the versines. *Bulletin of the Railway Congress*, November 1931.

(2) HÖFER :

a) « Die Absteckung von Gleisbogen aus Evolventenunterschieden » (Pegging curves by means of the differences of developed length), Berlin, 1927;

b) « Die Absteckung von Weichenverbindungen nach dem Evolventenverfahren » (Pegging points [turn-outs] by means of the developed length). *Zeitschrift für Vermessungswesen*, 1933, fasc. 19.

SCHRAMM :

c) « Der vollkommene Gleisbogen, seine Gestaltung als Kurve mit stetigem Krümmungsverlauf » (The perfect curve, and how to get it as a curve of continuous curvature), Berlin 1931;

d) « Das Winkelbildverfahren zum Abstecken von Bogen » (Pegging curves by the angles diagram method), *Zeitschrift für Vermessungswesen*, 1934, fasc. 3 and 5;

e) « Winkelbildverfahren und Gleisbogengestaltung » (The angles diagram method and the laying in of curves), *Organ für die Fortschritte des Eisenbahnwesens*, 1933, fasc. 18;

f) « Zeichnerische Ermittelung von Bogenpfeilhöhen » (Graphical method of calculating the versines of curves), *Gleistechnik und Fahrbahnbau*, 1934, fasc. 9;

g) « Gleisverziehungen, verzerrte und verkrümmte Lagepläne » (Defects in the track-layout distorted and displaced), *Verkehrstechnische Woche*, 1933, fasc. 50 to 52;

PETERSEN :

h) « Der Übergangsbogen im Eisenbahngleis » (Railway transition curves). *Organ für die Fortschritte des Eisenbahnwesens*, 1932, fasc. 22;

i) « Der Übergangsbogen im Strassenbahngleis (Tramway transition curves), *Die Verkehrstechnick*, 1933, fasc. 15-16;

k) MOLL : « Das Kurvenabstecken durch graphische Ermittelung » (Pegging curves by graphical methods), *Schweizerische Zeitschrift für Vermessungswesen*, 1933.

added together in turn and the sums so obtained are then used as the ordinates after reduction to a suitable scale. We get in this way the « *angles diagram* » of the curve, which gives an idea of the curvature of the given curve. From this diagram the distances of the new curve from the old are easily found.

This method has the following advantages over the old processes of pegging curves :

a) Very great accuracy not equalled by any other method. A great number of checks have actually shown average errors of only 1 to 3 mm. (3/64 to 1/8 inch) in the versines at the fixed points.

b) Very clear presentation thanks to the graphical relation of the angles diagrams, whence :

c) suitable solutions are sure to be found, even in difficult cases, and a large number of variants can be examined quickly.

d) Circular curves of any radius and transitions between circular curves can be pegged without any extra work, whereas with the old methods it was frequently necessary to make complicated interpolations in the tables, as well as tedious calculations.

e) Complete independence from the nature of the site : tunnels, high embankments, deep cuts, bridges, etc... not interfering with the pegging.

f) The main part of the work is done on paper in the office. As a result, the work is little affected by weather conditions (frost, snow, fog, etc.).

g) A steel tape and a simple instrument for measuring the versines make up the whole equipment needed (other instruments such as the theodolite, prismatic optical, target, levelling rod, boning rod, etc., being unnecessary).

h) Much time and work saved. Experience shows that better results and more accurate pegging are obtained with this method, in one fifth of the time required with the now out of date trigonometrical methods.

This method can be used with the greatest facility after a few practical applications, as it requires almost no mathematical knowledge. Against this, the beginner first trying it has to make full use of his imagination. As it is difficult to appreciate the method by any purely theoretical explanation, we attach great importance, in the following description, to a fully worked out example. The theory of the method, on the other hand, is dealt with very briefly, as it is not essential for understanding the practical part (chapter C). A full study of the application of the method is obviously impossible within the scope of this article. We have had to give up any idea of describing many applications and numerous expedients such as, for example, when pegging turn-outs on curves, for which the method is most suitable in many cases (see foot note 2, *b*).

B. — Theoretical principles.

2. — Base line and new curve.

B in figure 1 is the « *base line* » off which the new curve (B) is to be pegged out. The base line is in most cases an existing curve of irregular curvature. It may be — especially when constructing new lines — a polygonal layout or a given or imaginary circular arc.

For the sake of simplicity, B and (B) may be taken as having a common origin 1 = (1). Let us imagine, on the base line B, a constant « arc section » Δ

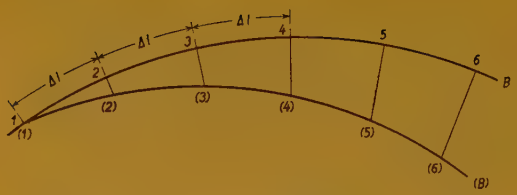


Fig. 1. — Base line B and new curve (B).

which is marked off in succession, starting from point 1. We thereby obtain the points 2, 3, 4... The normals to B drawn through these points meet (B) at points (2), (3), (4)... The lengths 1-(1), 2-(2), 3-(3), 4-(4)... will be called the « *distances* » from the curve (B) to the base line B, and be designated by e_1, e_2, e_3, e_4...; they can be taken as ordinates plotted relatively to the curved axis B of the abscissæ. We now propose to peg out the new curve (B) by marking off the distances e normally to the base line B. The object of the angles diagram method is seen to be the determination of the distances e.

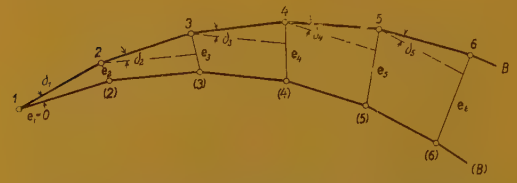


Fig. 2. — Polygonal layouts B and (B) inscribed in the base line and the new curve.

If we join by straight lines points 1 and 2, 2 and 3, 3 and 4..., and in the same way points (1) and (2), (2) and (3), (3) and (4)..., we get the two polygonal layouts of figure 2. Through points 2, 3, 4..., we draw lines parallel to the sides (2)-(3), (3)-(4), (4)-(5)... and we indicate by δ_1, δ_2, δ_3, δ_4 the angles of inclination (measured on the arc) on the corresponding sides of the polygones. Figure 3 shows, as a detail of figure 2, any two adjacent points n and $n + 1$. From point n and to point $n + 1$, the distance between the two polygonal layouts differs by the value Δe. If the angle δ_n is small (as in all practical cases it is sufficient to take $\delta_n \leqslant 0.11$), we get with close enough accuracy the equation.

$$\Delta e = \Delta l \cdot \delta_n \quad . \quad . \quad . \quad (1)$$

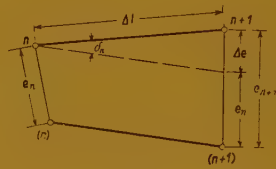


Fig. 3. — Detail of figure 2.

Consequently, from figure 2, we obtain :

$$e_1 = 0;$$
$$e_2 = \Delta l \cdot \delta_1;$$
$$e_3 = \Delta l \cdot \delta_1 + \Delta l \cdot \delta_2 = \Delta l \cdot (\delta_1 + \delta_2);$$
$$e_4 = \Delta l \cdot \delta_1 + \Delta l \cdot \delta_2 + \Delta l \cdot \delta_3 = \Delta l \cdot (\delta_1 + \delta_2 + \delta_3);$$

and generally :

$$e_{n+1} = \Delta l \cdot \sum_{i=1}^{i=n} \delta_i \quad . \quad . \quad . \quad (2)$$

If the length of arc be assumed to be infinitely small ($\Delta l = dl$) this equation, using the symbols of the integral calculus, can be written in the form

$$e = \int \delta \cdot dl \quad . \quad . \quad . \quad . \quad (2a)$$

The differential and integral calculus, however, is not used in this article.

By equation (2), we can now calculate the distances e for each point of the polygon by addition, if the different angles δ are known. We have therefore to find a graphical representation for the two

arcs (or polygons) B and (B) to be able to read off the different angles δ in the form of lengths on the drawing and to add them together graphically. This problem is solved by the graphical method given below.

3. — The angles diagram.

The base line B will be considered as the « *original* » reproduced on a drawing. The lengths measured on the original (fig. 4*a*) from an agreed point of origin A are represented by l, and the angles at the centre (= angles of inclination to the initial tangent at A) described on the lengths l, by φ. In the plan (fig. 4*b*),

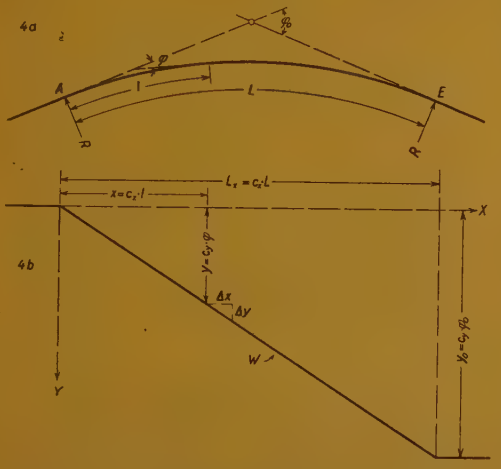


Fig. 4*a*. — Original (circular curve with end tangents).
Fig. 4*b*. — Angles diagram.

a system of rectangular co-ordinates X, Y is chosen and the two following equations written

$$x = c_x \cdot l \quad . \quad . \quad . \quad . \quad (3)$$

$$y = c_y \cdot \varphi \quad . \quad . \quad . \quad . \quad (4)$$

in which c_x is the « *scale of the lengths* », an indefinite number, and c_y the « *scale of the angles* », which is expressed as a length (centimetres) because it fixes the ratio between the length (y) and an indefinite number (φ = angle measured on the arc). A « *figurative line* » W, the principal characteristic of which is that its ordinates y correspond to the angles at the centre φ of the original (equation 4), corresponds in the figure (fig. 4*b*) to the original line B. This is the reason for calling it the « *angles diagram* » W of the original B. The following observations are the result of a simple consideration of the problem :

a) The angles diagram of a *straight line* is a straight line parallel to the axis X, that is to say, horizontal.

b) The angles diagram of an *arc of circle* of radius R is a straight line, the inclination of which to the axis X is

$$\frac{dy}{dx} = y' = \frac{c_y}{c_x} \cdot \frac{1}{R}$$

For simplicity we will write

$$\frac{c_y}{c_x} = c_r \quad . \quad . \quad . \quad . \quad (5)$$

c_r being the scale of the curvatures. We thus get

$$y' = \frac{c_r}{R} \quad . \quad . \quad . \quad . \quad (6)$$

In other words the slope of the angles diagram to the axis X is proportional to the curvature of the arc. In the case of right hand curves we admit that the imaginary line drops from left to right (for example fig. 4*a*, *b*), and that it rises when left-hand curves are in question (fig. 5 *a*, *b*).

c) The angles diagram of a *transition curve* of linearly varying curvature $\frac{1}{r}$ is a parabola of the second degree (fig. 5 *a*, *b*). Thus for example, the angles diagram of a circular curve (left-hand curve) with transitions and tang-

ents at both ends (fig. 6*a*) has the form shown in fig. 6*b*.

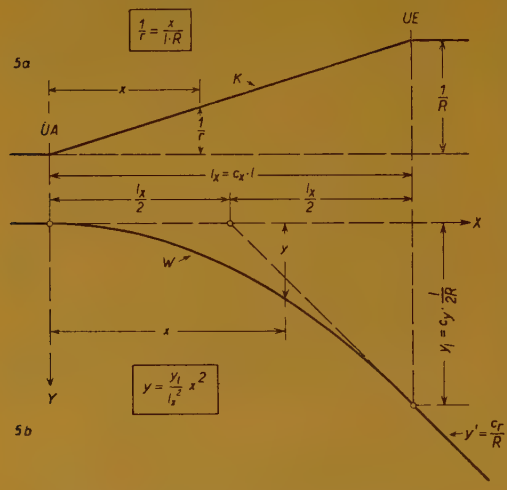


Fig 5*a*. — Transition curve with variable linear curvature (not drawn to scale).

Fig. 5*b*. — Angles diagram.

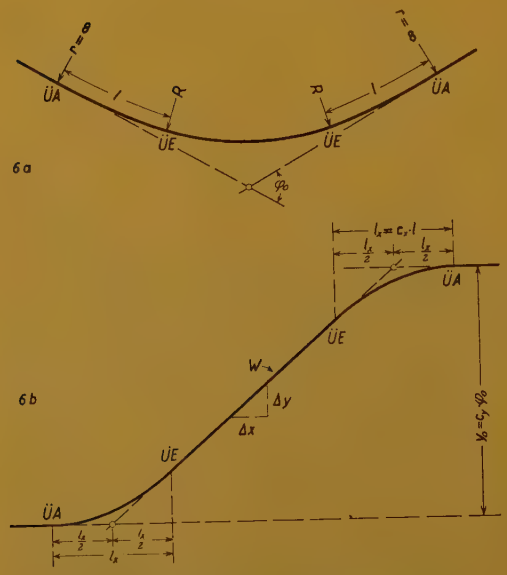


Fig. 6*a*. — Original (circular curve with transitions and end tangents).

Fig. 6*b*. — Angles diagram.

d) The angles diagram of a *polygonal layout* (fig. 7*a*) resembles a flight of steps (fig. 7*b*). The steps, with the abscissæ lengths $p_x = c_x . p$ [equation (3)], correspond to the sides p of the original, and the uprights of the steps with heights $\Delta y = c_y . \Delta\varphi$ [equation (4)] to the angles $\Delta\varphi$ of the original.

e) The angles diagram of *any given curve* is obtained in the following manner : Let us imagine points marked off at equal but not too great distances Δl, on a rail of the curve in question. These points as a whole represent a polygonal layout inscribed in the given curve. The ordinates of the angles diagram of this polygonal layout are found by measuring the versines at the different points with a tape 2. Δl long, adding them together in turn, and marking off the different totals as ordinates y, from a horizontal line on squared (millimetric) paper. In the case of a right hand curve we get, in this way, an angles diagram similar to figure 8. The reason why this construction gives accurate results is that the different versines are proportional to the angles of the polygon.

According to equation (3), the *abscissa section*

$$\Delta x = c_x \cdot \Delta l \quad . \quad . \quad . \quad (7)$$

corresponds on the drawing board to the arc section Δl.

In the German State Railways permanent way inspection coaches, the angles φ of the curve run over are drawn on the diagram as ordinates by means of a gyrocompass. The inspection coach also gives the angles diagrams of the curves together with the scales :

$$c_x = 1 : 6600 \text{ and}$$
$$c_y = 11.4 \text{ cm.}$$

In practice, especially on long curves of small radius, a system of oblique co-

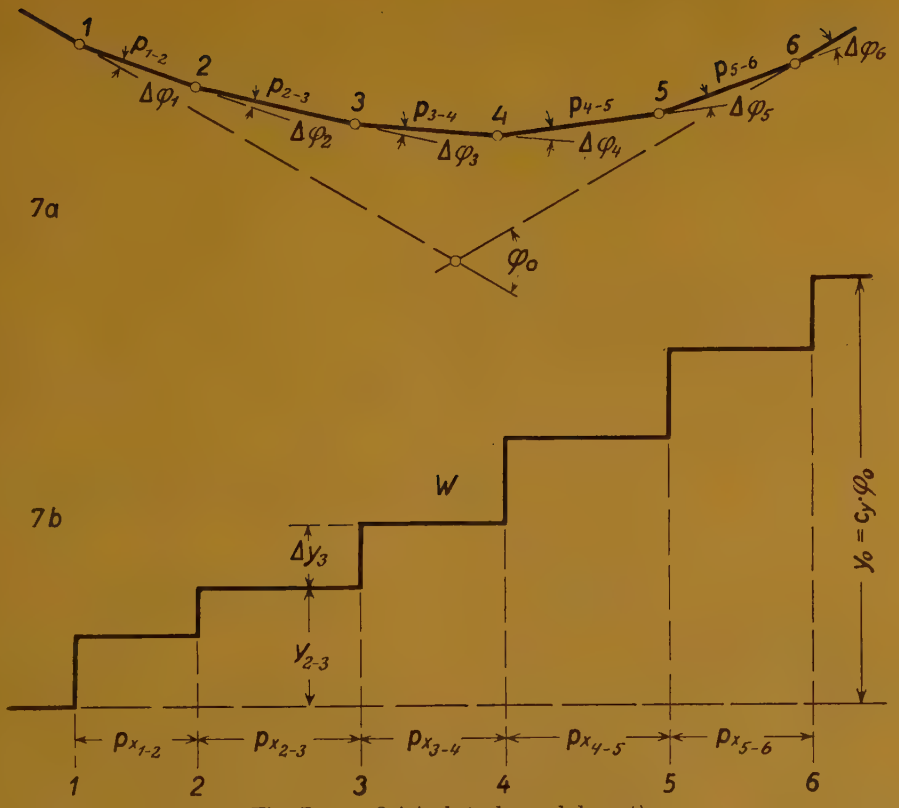


Fig. 7*a*. — Original (polygonal layout).
Fig. 7*b*. — Angles diagram.

ordinates, with the axis of the X's inclined, is frequently used in place of vertical ordinates. The advantage of this is that the figurative line of a curve rises less rapidly so that its height is less on the diagram and this helps the work. We then speak of a distorted or « *deformed angles diagram* » or of « *reduced versines* ». Figure 8, for example, under these conditions can assume the form shown in figure 9. The « *extreme parallels* » corresponding to the tangents at the ends of the curve are at an angle to the horizontal. This slope we will call the « *ratio of deformation* » tan β. In figure 9, for example, tan β has been taken as equal to—0.4. Using this deformed diagram, the abscissæ are also measured horizontally and the ordinates vertically; besides in the angles diagram the lengths measured horizontally are the only ones taken into account. The above equations remain applicable to the deformed diagram provided that, from figure 9, we again designate by y' the ratio of a vertical to the corresponding horizontal segment : $y' = \frac{\Delta y}{\Delta x}$. We use the deformed diagram in the example studied below.

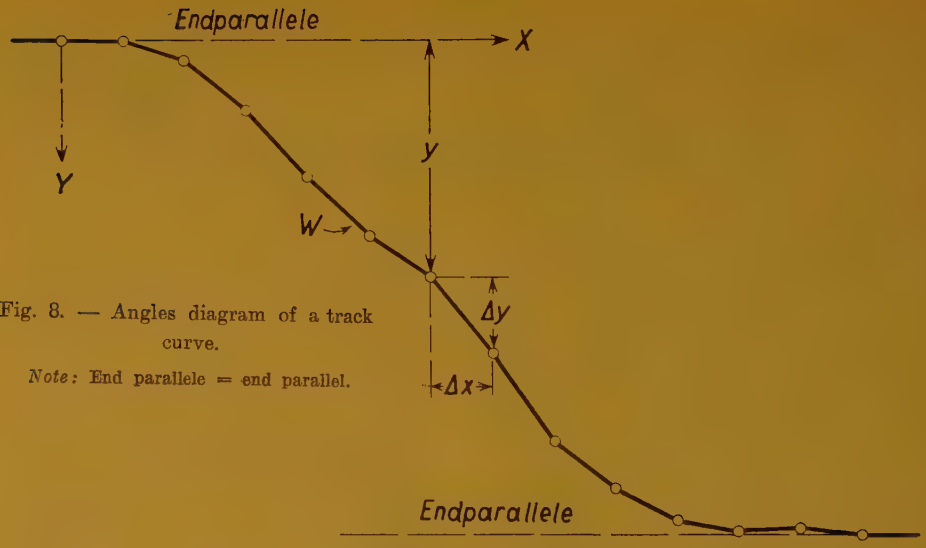


Fig. 8. — Angles diagram of a track curve.

Note: End parallele = end parallel.

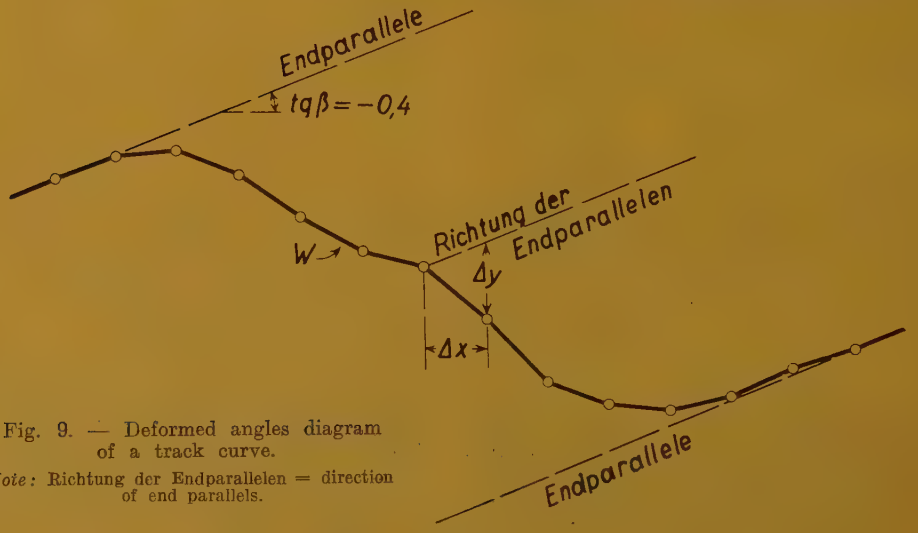


Fig. 9. — Deformed angles diagram of a track curve.

Note: Richtung der Endparallelen = direction of end parallels.

4. — Calculation of the distance *e*.

When the angles diagram W has been drawn relatively to the base line and also the angles diagram E of the new curve to be pegged out, or what is called the « *project* » (fig. 10*a*) the differences of the ordinates $d = y_W - y_E$ represent nothing other than the angles δ of figure 2. We have in fact from equation (2) :

$$d = c_y \cdot \delta$$

or

$$\delta = \frac{d}{c_y} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

We therefore obtain from equation (2), for all the points, the distances e wanted by adding together in turn with a pair of dividers the differences d and

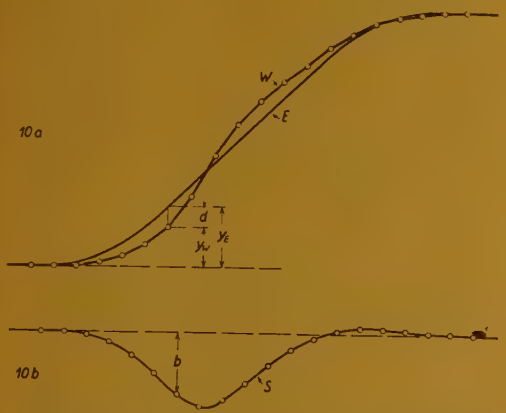


Fig. 10*a*. — Angles diagram W and project E.
Fig. 10*b*. — Additions line S.

by marking off on a horizontal plotting line the different sums as ordinates, i. e. in drawing the « *additions line* » for W and E (fig. 10*b*).

There only remains to multiply the ordinates $b = \Sigma d$ of the additions line by the scale coefficient in order to get the real distances e in the original.

Indeed, writing from equation 7, $\Delta l = \frac{\Delta x}{c_x}$ and from equation (8), $\delta = \frac{d}{c_y}$, equation (2) can be modified as follows :

$$e = \Sigma \Delta l \cdot \delta = \Sigma \frac{\Delta x \cdot d}{c_x \; c_y} =$$

$$= \frac{\Delta x}{c_x \cdot c_y} \cdot \Sigma d = \frac{\Delta x}{c_x \cdot c} \cdot b . \quad (2b)$$

Let us introduce the new notation

$$c_b = \frac{\Delta x}{c_x \cdot c_y} \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

and call this value the « *scale of widths* », Equation (2) them becomes

$$e = c_b \cdot b \quad . \quad . \quad . \quad . \quad . \quad . \quad (2c)$$

Equation (2) can still be written in another form, frequently used. From equation (2*b*) we have :

$$e = \frac{1}{c_x \cdot c^x} \cdot \Sigma \Delta x \cdot d$$

in which the product $\Delta x \cdot d$ is merely the area (in cm²) of the band lying between the angles diagram W and the project E : Consequently $\Sigma \Delta x \cdot d$ represents the area of the whole zone to a given point lying between W and E. If this area be designated by F, the equation can be written as follows :

$$e = \frac{1}{c_x \cdot c_y} \cdot F. \quad . \quad . \quad . \quad . \quad (2d$$

The calculation of the distances e between the new curve and the base line is therefore reduced to a simple calculation of the areas, when the angles diagrams W and E of the base line and of the new curve are given.

Equations (2) to (2*d*) all represent the same thing though in a different form. They are the basis of the whole method. In these equations, as in all those which follow, the dimensions are to the same scale, remembering, however, that c_x, δ, φ, y', and c_b are indefinite numbers, whereas Δx, Δl, d, R, e, b, c_y and c^r are lengths (in cm.) and F an area (in cm²).

After these brief theoretical considerations, we will give an example to illustrate the pegging of a curve.

C. — Example : pegging a curve.

5. — Selection of the arc section Δl and measurement of the versines.

If an existing curve be used as the base line it must first of all be divided

into arc sections Δl long. The values of Δl can lie between 500 and 1 000 centimetres. As a rule, Δl is made half the proposed distance between the fixed points of the track. For example, if these points be 15 m. apart, Δl would be 750 centimetres; if 20 metres apart, Δl would be 1 000 centimetres. Values exceeding $\Delta l = 1\,000$ cm. are rarely used if it is desired to measure the versines by means of a tape, as when the tape is longer than 20 metres, the measured versines are usually too inaccurate, especially if there is any wind. The ordinates corresponding to longer tapes can only be measured accurately by means of the *Höfer optical instrument*. In the case of curves of less than 200 metres radius, the length Δl selected will not exceed 500 centimetres.

When the different dividing points have been determined and marked in chalk on the rail, preferably one near the centre line of the double track, the versines are measured in turn at each of the dividing points using a tape 2. Δl long. The measured versines h are entered into a field notebook (in centimetres). The measurements are continued at both ends of the curve for at least 50 metres along the straight. When measuring up, an improvised instrument designed for the purpose is used; it consists of two wood handles with a tape and a scale and is so arranged that the negative ordinates up to 1 centimetre can be also read off without having to go from one side of the rail head to the other. The versines are read to an accuracy of half a millimetre.

When recording the versines in the field notebook, care must be taken to give them the correct signs. If, for example, the versines of a right hand curve are considered as positive, those of a left hand curve must obviously be shown as negative.

Our example deals with a 700-metre radius curve to the left. The fixed points should be spaced 20 metres apart. We consequently take $\Delta l = 1\,000$ cm. So as not to have to record only negative versines for the curve, we will only take the versines corresponding to the left hand curve as being positive. *Table 1* reproduces the complete entries in the field notebook. Column 1 gives the kilometres, and column 2 the measured versines h.

We then select the scale of the widths c_b (see § 4). Usually $c_b = 5$ when the corrections to be made are small, and $c = 10$ when they are large. Values of $c_b > 10$ are not used as a rule so that the results may be reasonably accurate. In our example we take $c_b = 10$.

In order to get the angles diagram of the curve the versines must be added up successively, the additions be multiplied by the « *scale of the versines* » c_h and marked off as ordinates starting from a horizontal plotting line. For the scale of the versines we have the equation

$$c_h = 2 : c_b \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

or in the case in question

$$c_h = 2 : 10 = 1 : 5.$$

To prevent the angles diagram from rising too quickly and its height being excessive when plotted on paper, we use the deformed figuration mentioned above (§ 3). To do this the actual versines are not added up as measured, but each versine h is reduced by a suitably selected amount k. In our case, the heights measured varied on the circular curve between 5 and 8 cm. (see table 1). We therefore select the value $k = 5$ cm.

Table 1.

1	2	3	4
Kilo-metres.	h	$h_k = h - k$	Σh_k
	Centi-metres.	*Centi-metres.*	*Centimetres.*
9.370			± 0.00
380	— 0.15	— 5.15	— 5.15
390	+ 0.45	— 4.55	— 9.70
400	- 0.45	— 5.45	— 15.15
410	+ 0.05	— 4.95	— 20.10
420	— 0.70	— 5.70	— 25.80
430	+ 1.80	— 3.20	— 29.00
440	+ 0.50	— 4.50	— 33.50
450	+ 2.35	— 2.65	— 36.15
460	+ 5.35	+ 0.35	— 35.80
470	+ 5.10	+ 0.10	— 35.70
480	+ 7.20	+ 2.20	— 33.50
490	+ 5.90	+ 0.90	— 32.60
500	+ 5.85	+ 0.85	— 31.75
510	+ 8.35	+ 3.35	— 28.40
520	+ 6.00	+ 1.00	— 27.40
530	+ 6.15	+ 1.15	— 26.25
540	+ 8.90	+ 3.90	— 22.35
550	+ 7.75	+ 2.75	— 19.60
560	+ 5.20	+ 0.20	— 19.40
570	+ 5.70	+ 0.70	— 18.70
580	+ 6.80	+ 1.80	— 16.90
590	+ 6.75	+ 1.75	— 15.15
600	+ 4.80	— 0.20	— 15.35
610	+ 6.55	+ 1.55	— 13.80
9.620	+ 6.00	+ 1.00	— 12.80
630	+ 6.20	+ 1.20	— 11.60
640	+ 6.75	+ 1.75	— 9.85
650	+ 7.40	+ 2.40	— 7.45
660	+ 5.85	+ 0.85	— 6.60
670	+ 8.30	+ 3.30	— 3.30
680	+ 6.60	+ 1.60	— 1.70
690	+ 9.05	+ 4.05	+ 2.35
700	+ 5.95	+ 0.95	+ 3.30
710	+ 8.15	+ 3.15	+ 6.45
720	+ 7.35	+ 2.35	+ 8.80
730	+ 4.70	- 0.30	+ 8.50
740	+ 5.10	+ 0.10	+ 8.60
750	+ 2.10	— 2.90	+ 5.70
760	+ 2.00	— 3.00	+ 2.70
770	+ 2.15	— 2.85	— 0.15
780	+ 1.50	— 3.50	— 3.65
790	+ 1.20	— 3.80	— 7.45
800	— 0.95	— 5.95	— 13.40
810	— 0.15	— 5.15	— 18.55
820	± 0.00	— 5.00	— 23.55
830	+ 0.35	— 4.65	— 28.20
840	— 0.10	— 5.10	— 33.30
$\sum_1^n h = 201.70$			$= \sum_1^n h_k$

(we could equally well take $k = 6$ cm. or $k = 7$ cm.).

The reduced versines $h = h - k$ are entered in column 3 in the field notebook, and in column 4 the h_k's are added successively. The additions (Σh_k) are plotted half a space out of line with the h_k's.

Let n be the total number of versines measured. To make sure no error has been made in the calculation we use the equation :

$$\sum_1^n h = n \cdot k + \sum_1^n h_k$$

In our case (see table 1) with $n = 47$, we have for example

$$201.7 = 47 \times 5 + (-33.3).$$

6. — The segment of abscissa Δx and the layout of the angles diagram.

The section of arc Δl has now to be drawn down on squared paper. On the paper the « section of abscissa » Δx [cf. equation (3)] corresponds to the length Δl of the original curve. In accordance with the millimetric division of the paper we usually make

$$\Delta x = 1 \text{ or } 2 \text{ cm.}$$

In our example we take $\Delta x = 1$ cm. and mark off the kilometres on the paper accordingly (plate 1).

The differences Σh_k of column 4 of the field service notebook are them multiplied by the scale of the versines $c_h = 1 : 5$ and are drawn in vertically as ordinates y from a horizontal plotting line, taking care, in accordance with the way they have been entered in the field notebook, to mark off the y's between the points of division of the arc, that is to say to offset them by $\frac{\Delta x}{2}$ towards the right and consequently at 385, 395, 405...

(see plate 1, *a*). The last ordinate at point 845 is for example :

$$y_{845} = c_h \cdot \sum_{380}^{840} h_k = \frac{1}{5} \cdot (-33.30) = -6.66\,\text{cm}.$$

In the case of a left hand curve (as in our case, for example) the positive ordinates are drawn upwards and the negative downwards; for a right hand curve the contrary is the case.

This shows that through the deformation (reduced versines) horizontal straight lines no longer correspond to the end tangents of the curve, but « *extreme parallels* », the inclination of which to the horizontal is :

$$\tan \beta = - \frac{c_h \cdot k}{\Delta x} \quad . \quad . \quad . \quad . \quad . \quad (11)$$

In our case, $k = 5$ cm. and

$$\tan \beta = - \frac{\frac{1}{5} \cdot 5}{1} = -1.$$

When tracing, as shown at points 535 to 565, a stepped line by drawing lines paralled to the extreme lines, through the different points, the angles diagram of the polygonal layout formed by the points marked on the rail is obtained. This stepped line need not be traced in, however, because the points marked off from the field notebook are as a rule the only ones needed in subsequent work (shown inside circles on the plates) later on. The stepped angles diagram (see § D) need only be drawn when any indifferent polygonal layout, with sides of different lengths, is used as the base line.

7. — The project.

Plate 1, *b*, again represents the same angles diagram; the plotting line is not given as it is not required in what follows. To the angles diagram (W) of the given curve we have now to add that of the future curve to be pegged out. This we call the « project « (E). Projects, of course, can vary ad infinitum, as we can use different radii and different lengths of transition. It is important, however, that the position of the project suit the conditions laid down so far as the end tangents of the new curve are concerned.

The ordinates of the additions line (S) for the differences between W and E (plate 1, *c*) represent the distances *e* wanted [equation (2*c*)]. For the end tangents of the new curve to coincide with those of the old one, the project must be so set out that the additions line gives, at the beginning and end, $b = 0$. This will be the case if firstly the end parallels W and E coincide and if, secondly, the sum of the differences of the positive ordinates *d* between W and E is as great as that of the negatives *d* or, which comes to the same thing, if the project is such that the differential areas between W and E balance out ($\Sigma d = 0$). To attain this result, the following procedure is followed :

To start with, the end parallels of the project are fixed, these corresponding to the end tangents of the curve. In the present case, these have the inclination calculated above ($\tan \beta = -1$) with the horizontal and should be drawn to fit as closely as possible the points of the angles diagram W on both sides of the curve. For this purpose, take a thin wire and stretch it above the angles diagram so that it fits the points well and compensates the differential areas. When an apparently suitable project has been found by sight, the position of the wire is noted and the « *straight line of the project* » is pencilled in; this line is the angles diagram of the new circular curve.

and cuts the end parallels at two points C and D. We now begin to only add up, with dividers, the differences d, keeping in mind the signs, to make sure that the straight line of the project inscribed in it fulfils with sufficient accuracy the condition $\Sigma d = 0$. If then the final remainder is only a few centimetres this does not matter as this final error can be eliminated very simply as we shall see later. In the case of the trial summation, in connection with the project of plate 1, the remainder is $\simeq$ 2 1/2 cm. Provisionally, this project can be considered good enough.

The parabolas of the second degree corresponding to the transition curves now have to be constructed. For this, the length l of the transition must be known, and this depends on the radius of the curve and the speed. The straight line of our project has the inclination $y' = 1.412$ in the direction of the end parallels. To this inclination, from equation 6, corresponds the radius $R = \frac{c_r}{y'}$. We do not yet know the scale of curvature c_r. Up to now, we have determined the constants Δl, Δx, and c_b, whence the other constants can be obtained by the following equations :

Scale of the lengths $c_x = \frac{\Delta x}{\Delta l}$. (12)

Scale of the angles $c_y = \frac{\Delta l}{c_b}$. (13)

Scale of the curvatures $c_r = \frac{c_y}{c_x}$. (5)

In our example we have, therefore :

$c_x = 1 : 1\,000$;

$c_y = \frac{1\,000}{10} = 100$ cm. ;

$c_r = \frac{100}{1 : 1\,000} = 100\,000$ cm.

The radius will therefore be :

$$R = \frac{100\,000}{1.412} = 70\,800 \text{ cm.} = 708 \text{ m.}$$

(The radius can be rounded off to the nearest metre.)

For this radius and the given speed V = 105 km. an hour, the superelevation is 13 cm. With a leading in gradient with a slope of 1 in 1 000, the necessary length of the transition then becomes $l = 1\,000 \times 13 = 13\,000$ cm. = 130 m. To the latter corresponds, in the angles diagram, the abscissa length

$$l_x = c_x \cdot l = \frac{1}{1\,000} \cdot 13\,000 = 13.00 \text{ cm}$$

The length $\frac{l_x}{2} = 6.50$ cm. is marked off horizontally from C. This gives us, on the extreme parallels and the « straight line of the project » the points G and H. The parabola of the second degree GH is now fixed by its two tangents CG and CH to the points of contact G and H. It is easily drawn in by the usual tangent construction, by dividing each of the tangents CG and CH into an equal number of equal parts and joining up the corresponding points of division. The parabola KL is found in the same way on the other side of the curve.

8. — Additions line.

The additions line is now drawn in. We will consider the differences of ordinates d as positive when W is above E, and negative when W is below E. The positive ordinates of the additions line are marked off upwards and the negative ordinates downwards. The easiest way to carry out the summation is to use a pair of dividers with an adjusting screw. When the dividers are too small, another reference line is used. The construction of the additions line

becomes an addition of surfaces (cf. equations 2*b*, 2*c*). Consequently the differences Σd should be offset half the width of the band $\frac{\Delta x}{2}$ to the right, as shown on plate 1*c*, at points 555, 560. The ordinate of the additions line at point 560, for example, is consequently

$$b_{560} = \sum_{375}^{555} d.$$

By the summation, we obtain the points in circles on the additions line (plate 1*c*). Where W is above E, the additions line rises, and when below, it drops. The additions line reaches a maximum or minimum where W and E cut one another. The *positive* ordinates of the additions line indicate the *adjustment to the right* to be made to the existing track, and the *negatives* the *adjustments to the left.*

It will be noticed that the additions line does not join up with the plotting line at its end, but at the point 850 its ordinate is $b_{850} = + 2.57$ cm., to which corresponds on the original curve an offset to the right of the end tangent $e = c_b \cdot b = 10. (+ 2.57) = + 25.7$ cm. (equation 2*c*), although we began by stating that the extreme tangent of the new curve should coincide with that of the old one ($b_{850} = 0$). This final error is corrected by what is called a « *reference line* » (as in making good the final error in levelling). At the beginning and end of the additions line a horizontal straight line is drawn to pass as accurately as possible through the points of the additions line. We get the points M and N at the middle of the transition curve, that is to say vertically below the points C and D. The straight line MN is drawn and we then get the points P, O, and S, T at the beginnings and ends of the transition curve (ÜA and ÜE). The second-degree parabolas PQ and ST are then drawn in. The line PQST now replaces the plotting line, that is to say we now take the ordinates *b* of the additions line as representing the distances, measured in the vertical direction, between the additions line and the reference line. Seeing that the additions line and the reference line coincide at the beginnings and ends (plate 1,*c)*, the amounts of adjustment $e = 0$ are shown, and the condition that the extreme tangents of the curve should remain unchanged is satisfied. The greatest amount of track adjustment to the left is at point 710; it is :

$$e_{710} = 10 \cdot (- 4.78) = - 47.8 \text{ cm.}$$

The greatest correction to the right (at point 600) is :

$$e_{600} = 10 \times 1.54 = + 15.4 \text{ cm.}$$

9. — Pegging out.

If the local conditions are such that the line can be adjusted in accordance with the additions diagram, the problem may be considered as solved, and the fixed points of the track ascertained from the additions diagram.

On the circular curve, the fixed points will be placed at the points of division of the arc, i. e. in our case, at points 550, 570, 590, 610, 630, 650, and 670. The beginnings and ends of the cant gradients are then decided (they coincide with the transition curves as a rule). It is as well to divide up the gradients by fixed points into a certain number of equal parts. The division selected is shown on the additions diagram (plate 1, *c*), by vertical lines. On the gradients the fixed points do not coincide, as a rule, with the points of division of the arc; this is the reason why it is neces-

sary to connect up therein the points on the additions line by means of a French curve to obtain a continuous line. The dimensions b can then be measured at each point and then between the division points.

If the track is very irregular between the points of division (kinks at rail joints, etc.) this insertion of intermediate points starting from the track can result in errors of some millimetres, as these operations naturally give accurately the adjustments at the division points (reference points) only. In practice, however, the errors will always be unimportant if the section of arc Δl is not selected too great (see § 5). Furthermore, the fixed points found should always be checked by measuring the versines, to make sure serious errors have not crept in accidentally. If too great errors be found (say over 1 cm.), they can still be easily eliminated subsequently, or at least reduced by offsetting the direction notches at the fixed points. Then too, it is always possible to ascertain at certain intermediate points the exact distances e plotted on the straight line (chord) joining the adjacent division points. We cannot, however, give any more time to this point here (see chapter D).

Table 2.

1	2	3	4
Point (*metres*).	e (*centimetres*).	K (*centimetres*).	$e + K$ (*centimetres*).
ÜA = 398.00	± 0.0	+ 96.5	+ 96.5
412.44	— 0.6	+ 96.5	+ 95.9
426.89	— 6.3	+ 96.5	+ 90 2
441.33	— 15.4	+ 96.5	+ 81.1
455.78	— 29.5	+ 96 5	+ 67.0
470.22	— 40.3	+ 96.5	+ 56.2
etc.			

A list of the fixed points, on the lines of *table* 2, is now prepared. In column 1 are shown the points (= km. from the fixed points), and in column 2 the distances $e = c_b \cdot b$ taken from the additions diagram (adjustments to the right +, to the left —). In column 3 is entered a fixed value K depending on the distance the fixed points should be from the new center line of the track and the edge of the rail from which it is to be measured. The edge to use is the one nearest the fixed points. In our case the gauge of the track is 143.5 cm., and the distance between centres of the two lines 350 cm.; the width of the head of the rail is 6.8 cm. We have therefore from figure 11 :

$$K = \frac{350}{2} - \left(\frac{143.5}{2} + 6.8\right) = 96.5 \text{ cm.}$$

K is a *positive* value if, when the correction $e = 0$, the fixed points come *to the right* of the rail edge in question (as for example in figure 11); in the opposite case, it must be given the negative sign.

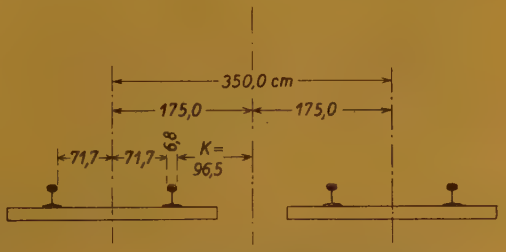


Fig. 11. — Measurement of fixed points in the track starting from the marker rail.

In column 4 have been calculated the values $e + K$, the distances between the fixed points and the edge of the left hand rail (edge of the rail near the centre line of the double-track line). The fixed points are then marked off, and the pegging is thus completed.

10. — Reference lines.

If the new curve were constructed by using the distances from the additions line to the plotting line (which ultimately led to an adjustment to the right of 25.7 cm.) it would show the exact conditions of curvature to satisfy the project drawn down on paper. As, however, the distances *b* marked off on the reference line PQST are different, these conditions of curvature must naturally have been modified in some way or another by the reference line.

A priori a straight line forming part of the reference line (for example the straight line QS) simply results in a rotation and, on the contrary, each parabola (for example the parabolas PQ and ST) give rise to a change of curvature. The curve represented by the project is therefore slightly « *distorted* » or « *bent* » subsequently by a reference line.

When the ordinates of the additions line do not entirely satisfy any conditions imposed (position of the end tangents, invariable points, etc.), these conditions can in a very large number of cases be met quickly and accurately by a suitable reference line without it being necessary to draw out a new project and a new additions line. The reference lines are therefore valuable auxiliaries when applying the method. Their use, however, depends on the following rules :

a) In a reference line, there must be no bend as this would result in a kink in the new curve;

b) A reference line should consist of second-degree parabolas tangent to one another, or of straight lines only. A straight line can be considered as a second-degree parabola with a versine $f = 0$;

c) The point of intersection of the end tangents of each parabola, measured horizontally, should fall in the middle between the points of contact. The parabolas are drawn in by means of the usual construction by tangents;

d) Over the length of a transition curve, the reference line, must consist of only *one* parabola (or a straight line); this is known as the « *transition parabola* » (such are, for example, the parabolas AB and DE, fig. 12). The reference parabolas inside a circular curve are called « main parabolas » (such are for example the parabolas BC and CD, fig. 12);

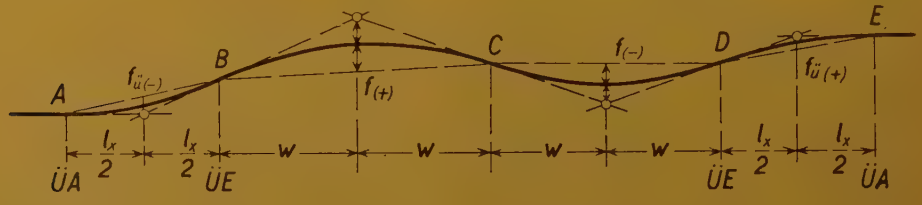


Fig. 12. — Example of a reference line.

e) Equations (15) and (16) below, conditioning acceptability of the transition parabolas, must be satisfied.

Let *w* be the half length of the abscissa of a main parabola, and *f* the versine. *f* is to be considered positive if the

parabola rests on its chord, and negative if it falls below it (cf. fig. 12). Let y' be the corresponding project inclination in the angles diagram. In place of the radius of the project $R = \frac{c_r}{y'}$ (equation 6) we get, owing to the deflection produced by the main parabola, the definitive radius

$$Rf = \frac{c_r}{y' \pm \frac{2 \cdot \Delta x \cdot f}{w^2}} \quad . \quad . \quad (14)$$

In this equation and the following ones, the + sign applies to *right hand curves* (project descending) and the — sign to *left hand curves* (project ascending). Δx, f, and w are to be marked off on the drawing in centimetres. If in place of f, we introduce in the equation the versine $f_{\ddot{u}}$ of a transition parabola following on the main parabola, we can obtain from this equation the radius of curvature at the end of the transition curve in question. This radius is slightly different from the radius of curvature R_f of the adjacent circular curve, because the transition parabola is usually inflected in a different direction, most often opposite to that of the adjacent main parabola (fig. 12). An error of curvature consequently occurs at ÜE, through a reference line, and naturally the error must not become too great if the pegging out is to be irreproachable. The use of reference lines therefore has to be kept within limits. We impose the condition that the error in curvature at ÜE must not exceed 5 % of the curvature of the adjacent circular curve. This restriction leads to the following equations of the conditions which the transition parabolas have to meet for being acceptable.

Case 1. — Transition parabolas at the origin or end of a circular curve. A transition curve, to be acceptable, must satisfy the equations :

$$\left.\begin{array}{l} \left| \frac{200 \cdot \Delta x}{l_{ox}^2 \cdot w^2} \cdot \frac{f \cdot l_{ox}^2 - 4 \cdot f_{\ddot{u}} \cdot w^2}{y' \pm \frac{2 \cdot \Delta x \cdot f}{w^2}} \right| < 5 \\ \left| \frac{200 \cdot \Delta x}{l_{ox}^2} \cdot \frac{4 \cdot f_{\ddot{u}}}{y' \pm \frac{2 \cdot \Delta x \cdot f}{w^2}} \right| < 5 \end{array}\right\} \quad (15)$$

The vertical lines mean that the absolute value of the expression between them is the only one of importance (whatever the sign). The first of these equations nearly always meets the requirements, as the second only applies to the rare case in which the transition parabola and the adjacent main parabola are both convex or concave. Should a *straight* reference line follow on a transition parabola (as for example plate 1, *c*) we have $f = 0$ and the equations take the simplified form

$$\left| \frac{200 \cdot \Delta x}{l_{ox}^2} \cdot \frac{4 \cdot f_{\ddot{u}}}{y'} \right| < 5 \quad . \quad (15a)$$

Case II (general case). — The transition curve connects a circular curve R_l (left hand) with a circular curve R_r (right hand) (fig. 13).

— The transition parabola, to be acceptable, must satisfy the equations :

$$\left.\begin{array}{l} \left| \frac{200 \cdot \Delta x}{l_{ox}^2 \cdot w_l^2} \cdot \frac{f_l \cdot l_{ox}^2 - 4 \cdot f_{\ddot{u}} \cdot w_l^2}{y'_l \pm \frac{2 \cdot \Delta x \cdot f_l}{w_l^2}} \right| < 5 \\ \left| \frac{200 \cdot \Delta x}{l_{ox}^2 \cdot w_r^2} \cdot \frac{f_r \cdot l_{ox}^2 - 4 \cdot f_{\ddot{u}} \cdot w_r^2}{y'_r \pm \frac{2 \cdot \Delta x \cdot f_r}{w_r^2}} \right| < 5 \end{array}\right\} \quad (16)$$

[Equations (15) are derived from the general equations (16) by making $f_l = 0$ and $f_r = f$].

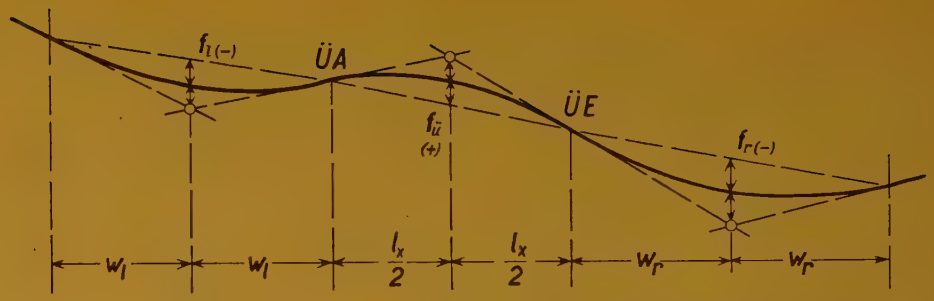


Fig. 13 — Example of a reference line. Transition parabola between two principal parabolas.

A reference line can be considered as being acceptable when the above conditions *a*) to *e*) are fulfilled. It must not be forgotten, however, that every main parabola consistent with equation (14) means an alteration in the radius of the original project, so that the new curve has as many different radii as there are main parabolas. For this reason, not more than one main parabola (or straight line) should be used.

11. — Examples of reference lines.

a) For the transition parabola shown in plate 1, *c*, we have $\Delta x = 1.00$ cm., $f_{\ddot{u}} = -0.15$ cm., $l_x = 13.00$ cm., and $y' = 1.412$. The check by means of equation (15*a*) gives the following result :

$$\left| \frac{200 \cdot 1}{13^2} \cdot \frac{4 \cdot (-0.15)}{1.412} \right| = -0.5 < 5.$$

The reference line is directly acceptable.

b) Plate 2, *a*, represents the same additions line as plate 1, *c*. Let us lay down the double condition that the curve must not be moved to the right at any point and that movement to the left should be the minimum actually necessary. This was possible straightaway, with the project, by using a slightly smaller radius or longer transition curves. The same objective can also be arrived at easily with the additions line of plate 2, *a*, by using a suitable reference line. The reference line ABCD supplies the solution. It is placed entirely above the additions line which it touches at its highest point (so that adjustments to the left should not become unnecessarily great). It is made up of two transition parabolas AB and CD and a main parabola BC. All that is necessary is to make sure that the parabola AB is acceptable, as it is more sharply curved than the parabola CD. The first equation 15 gives:

$$\frac{200 \times 1}{13^2 \times 7.745^2} \cdot \frac{(+0.60) \times 13^2 - 4 \times (-0.38) \times 7.745^2}{1.412 - \frac{2 \times 1 \times (+0.60)}{7.745^2}} = 2.7 < 5.$$

The reference line ABCD is therefore acceptable.

c) Let us suppose the width between the two tracks of the double line has to be increased by 50 cm. at the end of the curve, by moving the right hand track 50 cm. to the right. Adjustments to this track relatively to the left hand track taken as the base line is readily found in this case by means of the reference

line AEFG (plate 2, *a*). Its distance to the additions line is, at its end, $\frac{50}{c_b} = \frac{50}{10} = 5$ cm. The reference line is acceptable as the curvature of its transition parabolas is less than that of the parabola AB checked above.

12. — Rotations of end tangents.

On plate 2, *b*, are reproduced the same angles diagram as on plate 1, *a-b*. Let us suppose the end tangent of the new curve is required to describe an angle $\delta = 0.01$ (measured on the arc) with that of the old curve, in a counterclockwise direction and that at point 850 the new tangent be at a distance $e_{850} = -25.0$ cm. (to the left) of the old curve.

The result of the rotation is that the angle at the centre of the curve is increased by the quantity δ. From equation (4), there is in the angles diagram a corresponding increase in the vertical distance of the extreme parallels and the ordinate value :

$$d = c_y \times \delta = 100 \times 0.01 = 1.00 \text{ cm}.$$

The end parallel of the project should be traced this amount *above* the end parallel of the angles diagram (see plate 2, *b*). In addition, the project must be arranged by trial and error in such a way that the additions line has, at point 850, the ordinate $\frac{e_{850}}{c_b} = \frac{-25}{10} = -2.50$ cm. The project with the slope $y' = 1.411$ ($R = 1.411 \frac{100\,000}{1.411} = 70\,900$ cm.) seems to meet the case. Plate 2, *c*, shows the additions line. In the end it becomes a straight line having relatively to the base line the slope :

$$b' = \frac{\Delta b}{\Delta x} = \frac{\delta}{c \cdot c_b} \quad . \quad . \quad . \quad . \quad (17)$$

This equation gives, in very general terms, the relation between the inclination b' of the additions line and the angle δ the new curve makes with the base line of the original at some point. In our case we get for the end straight line of the additions line :

$$b' = \frac{0\ 01}{(1 : 1\ 000) \times 10} = 1.$$

We then mark off at point 850 the length $\frac{25.0}{10} = 2.50$ cm. above the additions line. Through the point so obtained, we draw the reference line HKLP which terminates at the original straight line of the additions line. The operation is then completed.

If a still further condition be imposed as, for example, that the initial tangent of the adjacent track be moved parallel to itself 40 cm. to the right, this condition could be met by the reference line MNOP.

D. — Pegging from a given polygonal layout.

13. — As shown in Chapter C above, a section of constant arc Δl has been transferred to the curve to be used as the base line. The new curve therefore has been pegged out, as it were, from a polygonal layout, the whole of the sides of which are *equal* to Δl. We will now show, by an example, how to peg out a curve from a polygonal layout with *different* sides P. This is a problem which can arise, for example, when building new railway lines or roads, or when the pegging of a given curve with serious errors has to be corrected.

First of all the sides p and the angles of the polygon $\Delta\varphi$ (see fig. 7*a*) are determined, the latter either directly with the theodolite or indirectly by measuring

the versines. Let us suppose a polygonal layout with the apices 1, 2, 3, 4, the three sides $p_{1\text{-}2}$, $p_{2\text{-}3}$, $p_{3\text{-}4}$, the angles $\Delta\varphi_1$, $\Delta\varphi_2$, $\Delta\varphi_3$ and $\Delta\varphi_4$, and the straight sections of track at each end.

Table 3.

1	2	3	4	5	6	7	8
P	p	$p_x = c_x \cdot p$	$x = \Sigma p_x$	$\Delta\varphi$	$\Delta y = c_y \cdot \Delta\varphi$	$y = \Sigma \Delta y$	$p_x \cdot y$
	cm.	*cm.*	*cm.*	*Mesured on the arc.*	*cm.*	*cm.*	cm^2
1				0.0838	4.19		
	7 000	7.000				4.19	29.330
2			7.000	0.0902	4 51		
	7 840	7.840				8.70	68.208
3			14.840	0.1352	6.76		
	7 660	7.660				15.46	118.424
4			22.500	0.1271	6.36		
						21.82	

$\Sigma p_x \cdot y = 215.962$

Referring to *table 3*, column 1, gives the number of the apices, column 2 the measured sides p of the polygon, and column 5 the angles $\Delta\varphi$ of the polygon, measured on the arc. We select as scale for the lengths $c_x = 1 : 1\,000$, and for the angles $c_y = 50$ cm. We fill in in column 3 the segments of abscissæ corresponding to the sides of the polygon in the angles diagram :

$$p_x = c_x \cdot p = \frac{1}{1\,000} \cdot p$$

(equation 3). By successive additions of column 3, we obtain, column 4, the abscissæ $x = \Sigma p_x$. Column 6 gives the segments of ordinates corresponding to the angles of the polygon in the angles diagram $\Delta y = c_y \cdot \Delta\varphi = 50 \cdot \Delta\varphi$ (equation 4). By successive additions of column 6 we ascertain, column 7, the ordinates $y = \Sigma \Delta y$. With these abscissæ and ordinates (cols. 4 and 7) we have drawn in figure 14*a*, in stepped form, the angles diagram W of the given polygonal layout.

We now have to select a project E. Let us suppose the end tangents of the new curve are to coincide with the end straight lines of the polygonal layout. For this to occur, first of all the end parallels of W and E must coincide (so that the new curve and the polygonal layout may have the same angle at the centre), and also that the differential areas F between W and E must balance (so that at the beginning and the end we obtain $e = 0$). These conditions can be met, as in paragraph 7, by trial and error. This, however, is a tedious method, as in the present case when the diagram of the angles W is stepped with the steps of unequal length, a pair of dividers cannot be used to add them up graphically. The areas of the various differential surfaces must, on the contrary, be calculated and the added together. This takes much more time than when dividers are used

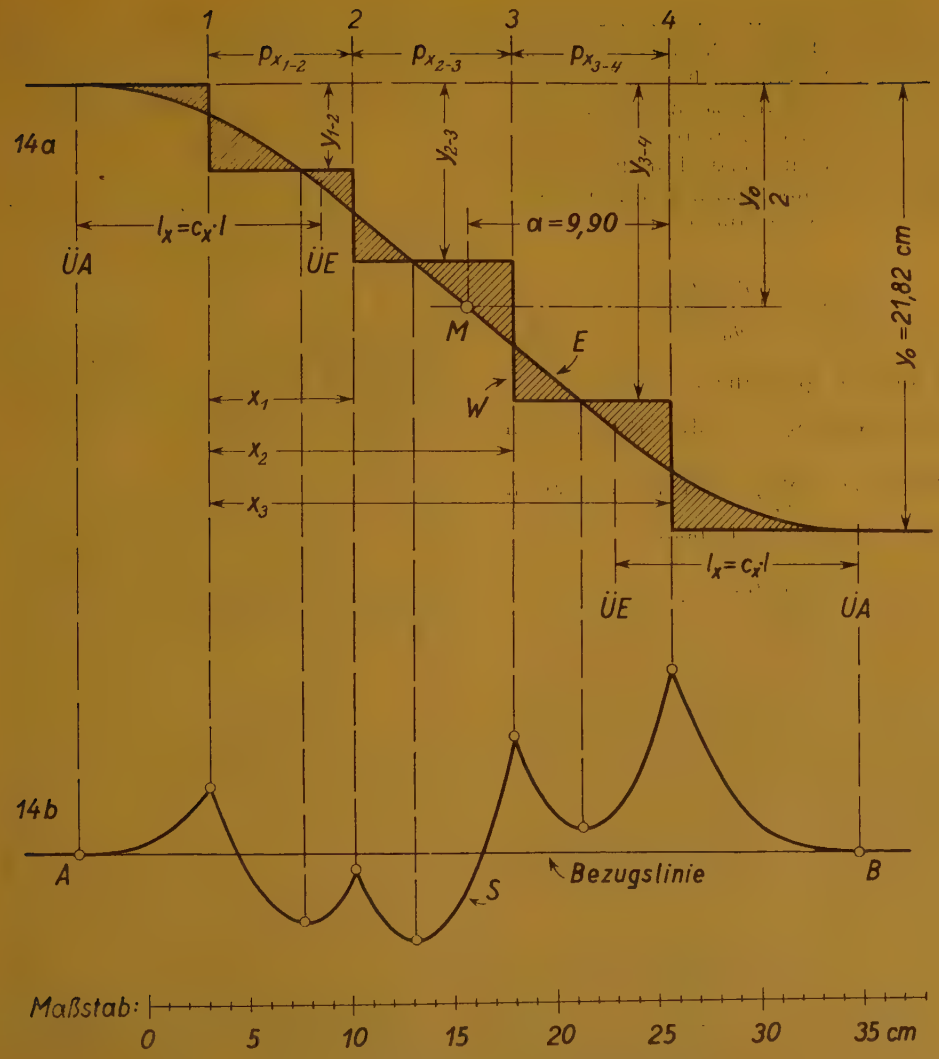


Fig. 14. — Pegging from a polygonal layout.
a) Angles diagram. — *b*) Additions diagram.
Note: Massstab = scale. — Bezugslinie = reference line.

as on plate 1, *b*, to add them up. It is advisable, therefore, in this case, to locate *by calculation* the centre M of the project E so that the imposed condition that the areas compensate one another be fulfilled from the start.

For this, the following consideration is made use of. W encloses, with the axis of the X's to the last (n^{th}) point of the polygon, the surface

$$F_0 = \sum_1^n p_x \cdot y.$$

If the differential areas between W and E are to balance, the surface enclosed by E with the axis of the X's to the last point must have the same area; in other words, the distance of the centre M of the project to the vertical at the point n, measured at equal distance from the ends parallels, must be (fig. 14*a*)

$$a = \frac{F_0}{y_0} = \frac{\sum_1^n p_x \cdot y}{y_0} \quad . \quad . \quad . \quad . \quad (18)$$

Column 8 gives the products $p_x \cdot y$. We find that $\sum_1^n p_x = 215.962$ cm². In addition, $y^0 = \sum_1^n \Delta y = 21.82$ cm. From equation (18) we must obtain :

$$a = \frac{215.962}{21\ 82} = 9.90 \text{ cm.}$$

This fixes the position of the point M (fig. 14, *a*). Any project which passes through M compensates the differential areas, it being understood, of course, that the transition curves at both ends are made of equal length.

Let us now take a project E having an inclination $y' = 0.8333$. The corresponding radius of circle is :

$$R = \frac{c_r}{y'} = \frac{c_y}{c_x} \cdot \frac{1}{y'} = \frac{50\ 000}{0.8333} = 60\ 000 \text{ cm.}$$

(equations 5 and 6). We also take the length of the transition $l = 12\ 000$ cm. The corresponding lengths of the abscissæ of the second degree parabolas, in the angles diagram, are consequently

$$l_x = c_x \cdot l = \frac{1}{1\ 000} \times 12\ 000 = 12 \text{ cm.}$$

W and E together now enclose the 8 cross hatched areas. On the length of the arc of circle are areas of triangles, and on the length of the transition curves areas bounded on one side by a parabola of the second degree. These latter are found by Simpson's rule (fig. 15) :

$$F = \frac{u}{6} \cdot (d_l + 4 \cdot d_m + d_r) \quad . \quad (19)$$

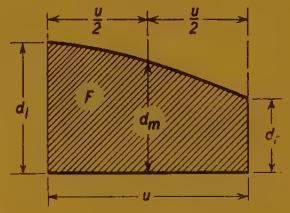


Fig. 15. — Calculation of the area by Simpson's rule.

The areas in square centimetres (cm²) are entered in column 2, *table 4*, and are positive and negative alternately. They are added together successively and the different ΣF's entered in column 3.

Table 4.

1	2	3	4	5
P	F	ΣF	$e = \frac{1}{c_x c_y} \cdot \Sigma F$	$b = e : c_b$
	cm²	*cm²*	*cm.*	*cm.*
1	+ 3.225	+ 3.225	+ 64.5	+ 3.225
	− 6.613	− 3.388	− 67.8	− 3.388
2	+ 2.588	− 0.800	− 16.0	− 0.800
	− 3.484	− 4.284	− 85.7	− 4.284
3	+ 9.910	+ 5.626	+ 112.5	+ 5.626
	− 4.485	+ 1.141	+ 22.8	+ 1.141
4	+ 7.696	+ 8.837	+ 176.7	+ 8.837
	− 8.867	− 0.030	− 0.6	− 0.030

The wanted distances are found in column 4 :

$$e = \frac{\Sigma F}{c_x \cdot c_y} = \frac{1\,000}{50} \cdot \Sigma F = 20 \cdot \Sigma F \text{ (eq. } 2d).$$

When laying out the additions line, we select a scale of widths c_b. Let us make $c_b = 20$. In column 5, the values $b = \frac{e}{c_b} = \frac{e}{20}$ (equation $2c$), are entered.

Transferring them to the corresponding points (that is to say to the ends of the differential areas in question) as ordinates from a horizontal plotting line gives the points in circles in fig. 14*b*.

It will be seen that, with the scales selected, the numbers in column 5 are the same as those in column 3. The ΣF's in cm² at the same time represent, in our case, the ordinates b of the additions line in cm. Multiplying them by $c_b = 20$ gives the distances e in the original. We could therefore have decided not to fill in column 4 and 5. Nonetheless, we have shown them in the table to bring out the co-relation between the magnitudes ΣF, e and b resulting from the three scales c_x, c_y, and c_b (equations 2 *c*, and 2 *d*).

Through the unavoidable errors in adding the areas, we obtained instead of $e = 0$, the value $e = 0.6$ cm. ($b = -0.03$ cm.); in other words, the straight section adjoining the polygonal layout is displaced, parallelly to itself, 0.6 cm. to the left. In figure 14*b*, this slight final error cannot be distinguished. If considered necessary, this error is eliminated by drawing a straight line connecting the origin A of the additions line with the end B and transferring the ordinates b to the straight line AB. To be quite correct, the points A and B must be connected by a reference line as on plate 1, *c*. However, the transition parabolas then become so flat that they cannot be drawn in. As the reference line is drawn horizontally from A to the left and B to the right, very slight kinks occur in the reference line at A and B. The length AB = 38.09 cm. The kinks at A and B then become :

$$b' = \frac{0.03}{38.09} = 0.000\,788.$$

The corresponding angle in the original, from equation (17), is

$$\delta = c_x \cdot c_b \cdot b' = \frac{1}{1\,000} \times 20 \times 0.000\,788 =$$

0.00 001 576 (measured on the arc) = 3.25″, practically equal to zero.

If we want to peg out other points of the curve at any points, starting from the polygonal layout, the complete additions line has to be drawn. From figure 14 *b*, it is made up, on the whole length of the circular curve, of parabolas *all of the second degree*, and in the length of the transition curves, of *cubic parabolas*. The second-degree parabolas are drawn down again by the usual method using tangents. The inclinations b' of the tangents to the parabola relatively to the horizontal are given by the equation

$$b' = \frac{d}{c_x \cdot c_y \cdot c_b} = \frac{d}{\Delta x} \quad . \quad . \quad (17a)$$

in which d again represents the difference of ordinates between W and E at the point in question. Thus, for example, at point 3 we have, for the left side area, $d = +4.15$ cm., and for the right side area, $d = -2.61$ cm. With the scales adopted

$$\Delta x = c_x \cdot c_y \cdot c_b = \frac{1}{1000} \cdot 50 \cdot 20 = 1 \text{ cm.}$$

Consequently, on the additions diagram, the tangents of the parabola have, at

point 3, to the left the inclination $b' = + 4.15$, and to the right the inclination $b' = - 2.61$. Moreover, the points of intersection of the tangents of the second-degree parabolas fall, as usual, in the middle (measured horizontally) between the points of contact. The cubic parabolas (on the length of the transition curves) are drawn down by locating, after calculating the corresponding differential surfaces in the angles diagram, a few intermediate points in the additions diagram, and joining them up with a French curve. The problem has then been solved.

Should we desire subsequently the additions diagrams to satisfy special conditions as to the distances e or the position of the end tangents, etc., we can, of course, proceed in the same way by using reference lines as explained in §§ 10 and 11. The case occurs more particularly when we want to correct the pegging out of a curve with serious errors. The reference line can then be arranged, as a rule, in such a way that at a number of fixed points $e = 0$. This reduces the fixed points to be moved to the number strictly necessary.

When pegging out from a given polygonal layout, such as the one just described, only three scales, c_x, c_y and c_b have been selected; in this case there is no constant « *segment of abscissa* » $\Delta x = c_x \cdot \Delta l$. Here again, however, a fixed value of Δx is obtained, according to equation (9), by

$$\Delta x = c_x \cdot c_y \cdot c_b \quad . \quad . \quad . \quad (9a)$$

This value of Δx is to be used in the equations of the reference lines, etc. (for example, in equations 14 to 17).

In the example taken, equation (9*a*) gives $\Delta x = 1$ cm. This also explains why the figures in column 5 of table 4 should be the same as those in column 3, seeing that from equations (2*c*) and (2 *d*) :

$$b = \frac{\Sigma F}{\Delta x} = \frac{\Sigma F}{1 \text{ cm}}.$$

Then only preliminary condition to be satisfied when pegging out from a polygonal layout such as has just been described — and in all cases when the angles diagram method is used — is that all the differences of ordinates between the angles diagram and the project lie within the limit

$$d \leqslant 0.11 \cdot c_y \quad . \quad . \quad . \quad . \quad (20)$$

(cf. § 2). This condition is usually satisfied when the different angles of the $\Delta\varphi \leqslant 12^{\circ}$.

E. — Pegging out new railway lines with long transition curves.

14. — The cubic parabola as transition curve and its drawbacks.

The superelevation gradients of main line curves are usually laid in on a *straight line* in a vertical plane; the transition should therefore be a *curve of varying curvature and rectilinear profile* (fig. 5*a*). We saw, from the examples given above, how to obtain a perfect pegging out of transition curves of this kind by using the angles diagram method, starting from a curve in the track or from a polygonal layout. No equation for the transition curve is needed!

What should be the procedure when, in connection with new railway lines, projected curves are to be drawn on the general drawings and then transferred to the site?

We know that the curve having linear curvature (fig. 5*a*), known as the « Clotoid » cannot be shown

analytically in a closed form. We have always had to be content with a curve which takes its place, and have used the *cubic parabola* or sometimes the sinusoidal, the lemniscate, etc.

The cubic parabola is pegged out as a transition curve as follows : The angle at the centre φ_o is given. We select the radius of circle R. This meets the end tangents of the curve at the two points B and B', the distance of which to the point of intersection of the tangents is

$$t = R \cdot \tan \frac{\varphi_0}{2} \quad . \quad . \quad . \quad . \quad (21)$$

The length l of the transition curve is selected to suit the radius, the speed and the cant gradient. From B the length $\frac{l}{2}$ is marked off on the end tangent and this gives ÜA, the origin of the transition. The pegging out of the cubic parabola

$$y = \frac{x^3}{6\ l \cdot R} \quad . \quad . \quad . \quad . \quad (22)$$

is then taken in hand, in relation to the end tangent on the axis of the x with ÜA as O. The point of the parabola corresponding to the abscissa $X = l$ is the end ÜE of the transition, the distance of which to the arc of circle BB' is

$$f = \frac{l^2}{24 \cdot R} \quad . \quad . \quad . \quad . \quad (23)$$

If, whilst not altering the centre, the radius R is shortened by this quantity f, this « *offset* » arc of circle touches the cubic parabola approximately at ÜE. This method of pegging out, formerly in general use, can only be employed however when the length of the transition

$$l < \frac{R}{4} \quad . \quad . \quad . \quad . \quad . \quad . \quad (24)$$

As a matter of fact, we get a « *kink* » at ÜE and a « *sudden rise* » in the line of pegs; then too the radius of curvature of the cubic parabola does not coincide at ÜE with the radius R—f of the adjacent arc of circle. If $l > \frac{R}{4}$, these errors become too considerable to be accepted. Then too, this method has the drawback that in the project and in the pegging out a distinction must be made between the « *initial* » arc of circle and the « *offset* » arc, without taking into account the fact that the « *offset f* » becomes very great for long transition curves.

When building new railway lines for high speeds, transition curves appreciably longer than those given by equation (24) will always be used in future. It then becomes impracticable to use the method of pegging out based on the cubic parabola. Various proposals have been made with a view to rectifying the cubic parabola or to use it in another way and so avoid the above mentioned errors. These suggestions have been outrivalled by the angles diagram method, which always gives, as shown in chapters C and D, perfect transition curves *when repegging existing railway lines*, without any equation being necessary for laying out these curves. This method, as we shall see later on, also enables us, *in the case of new constructions*, to study and peg out without error, in a simple way, transition curves of any length, of any desired curvature.

15. — Transition curves with linear variation.

The angle at the centre φ_o is given. The radius of circle R and the length l of the transition curve are selected in view of the speed and cant gradient. The curve is first of all drawn down in the general arrangement drawing and then transferred to the site in the form of a

symmetrical compound curve in three parts with the radii :

$$R_1 = \frac{4}{3} \cdot R,\ R,\ R_1 = \frac{4}{3} \cdot R.$$

Moreover, the lengths of the arcs of circle R_1 must be

$$L_1 = \frac{2}{3} \cdot l$$

(fig. 16*a*). The length t of the tangents is given by the equation

$$t = \frac{4}{3} \cdot R \cdot \operatorname{tg} \frac{\varphi_0}{2} \cdot \left[1 - \frac{\sin\left(\frac{\varphi_0}{2} - \frac{l}{2R}\right)}{4 \cdot \sin\frac{\varphi_0}{2}} \right] \quad (25)$$

The compound curve can then be marked off on the general arrangement drawing and pegged out on the site. Starting from point B, we mark off on the tangent the length

$$BA = \frac{l}{3}$$

This gives the point of origin ÜA of the transition curve, the end of which is the extreme point C of the arc of circle R. With this method of pegging, the arc of circle R (CC') falls into its definite position from the start; no « *offset f* » is needed. The segment of tangent AB and the adjacent arc of circle BC, of radius R, fit so well the future transition curve AC (not reproduced in fig. 16*a*) that the maximum distance of the transition curve from this datum line ABC, which maximum occurs at the middle of the transition curve, is only:

$$e_{max} = \frac{l^2}{96\,R} = 0.010\,417 \cdot \frac{l^2}{R} \quad . \quad (26)$$

For example, when R = 300 m. and l = 200 m., we get :

$$e_{max} = \frac{200^2}{96 \times 300} = 1.389 \text{ m.}$$

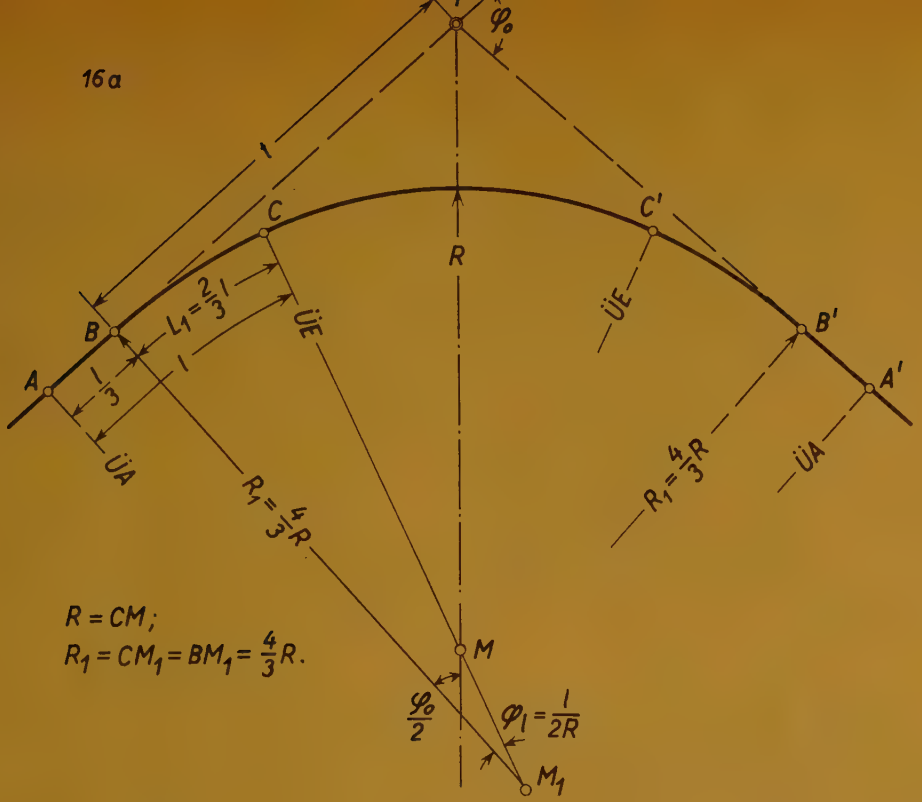
When drawing in the projected curves on the general drawings, all that is needed is to show them as compound curves, as in figure 16*a*; when pegging out, on the ground, a few points on the transition curve are enough. *Table 5* gives the distances e between the transition curve and the base line ABC for the consecutive tenth parts of the transition length l. The transition curve so obtained has a linear curvature (fig. 5*a*). It touches the arc of circle R at Üe (point C), with the exact radius of circle R, and is free from error.

Table 5. (Cf. fig. 16c.)

Distance from ÜA	e
ÜA $0.0 \times l$	0
$0.1 \times l$	$0.000\,167 \times l^2/R$
$0.2 \times l$	$0.001\,333 \times l^2/R$
$0.3 \times l$	$0.004\,500 \times l^2/R$
$0.4 \times l$	$0.009\,000 \times l^2/R$
$0.5 \times l$	$0.010\,417 \times l^2/R = e_{max}$
$0.6 \times l$	$0.009\,333 \times l^2/R$
$0.7 \times l$	$0.006\,750 \times l^2/R$
$0.8 \times l$	$0.003\,667 \times l^2/R$
$0.9 \times l$	$0.001\,083 \times l^2/R$
ÜE $1.0 \times l$	0

When first pegging out the curve for forming the roadbed, these points are amply sufficient. The fixed points in the track, however, have to be pegged out as described in chapter C or D, either from the line already laid in or from a previously established polygonal layout, as this is the only way to make sure of getting the greatest accuracy as regards the fixed points on the track.

When building a new railway line we should consequently make a distinction



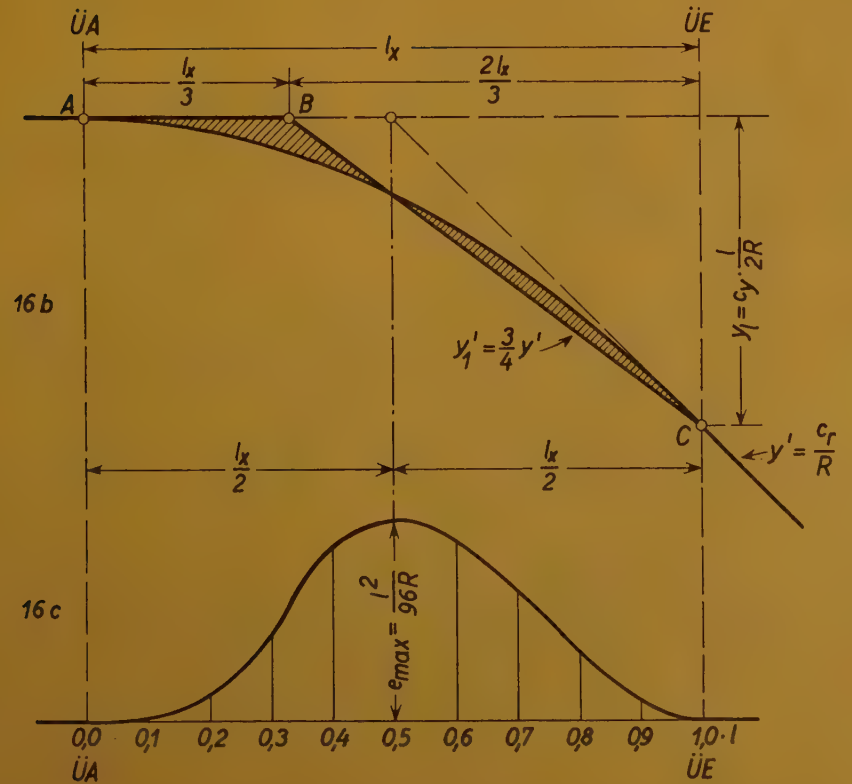


Fig. 16. — Pegging of new railway lines with long transition curves with linear variation.
a) Original. — *b*) Angles diagram of the transition curve and of the base line. — *c*) Additions line (cf. table 5).

between the *first pegging out* when forming the roadbed, deciding the boundaries, etc., and the *staking out by means of fixed points in the track*, for track laying and maintainance purposes. These two peggings are in fact called upon to meet somewhat different conditions. There is no need at all for them to coincide, and each is carried out independently of the other.

Figure 16*a-c* proves the pegging method described above. The second-degree parabola AC (fig. 16*b*) is the angles diagram of the transition curve (cf. fig. 5*a-b*). The straight line BC with an inclination

$$\frac{3}{4} \cdot y' = \frac{3}{4} \cdot \frac{c_r}{R}$$

is the angles diagram of the circular curve R_1 (fig. 16*a*), which touches the arc of circle R at point C. The summation (integration) of the differences of ordinates between the two angles diagrams ABC and AC gives the additions line (fig. 16*c*) with the distances e according to table 5. When $x = 0$ and $x = l$, we find $e = 0$, because the differential areas between the two angles diagrams compensate one another, as can be shown quite easily by means of figure 16*b*.

16. — Transition curves with parabolic variation.

The rectilinear arrangement of curves and superelevations is not the best possible owing to the variation of ÜR and ÜE. The variation of ÜE can be remedied by substituting parabolic for linear curvature (fig. 17*a*). To this curvature corresponds, as angles diagram (fig. 17*b*), the cubic parabola AC which is easy to construct with the information given in figure 17*b*. If in the examples given in chapters C and D, this angles diagram had been used for the transition curves, we should have had transition curves with parabolic curvature, as in figure 17*a*, instead of the second-degree parabolas (fig. 5*b*).

To peg out transitions of this kind, when building new lines, the procedure should be that of § 15. A *symmetrical compound curve in three parts* is drawn down with the radii

$$R_1 = \frac{9}{8} \cdot R, \quad R, \quad R_1 = \frac{9}{8} \cdot R.$$

The arcs of circle R_1 must be made the lengths

$$L_1 = \frac{3}{4} \cdot l$$

The length t of the tangents is given in this case by the equation

$$t = \frac{9}{8} \cdot R \cdot \operatorname{tg} \frac{\varphi_0}{2} \cdot \left[1 - \frac{\sin\left(\frac{\varphi_0}{2} - \frac{2}{3} \cdot \frac{l}{R}\right)}{9 \cdot \sin \frac{\varphi_0}{2}} \right] \quad (27)$$

To obtain the point of origin of the transition curve, on the tangent we must mark off starting from B (cf. fig. 16*a*) the length :

$$BA = \frac{l}{4}$$

Figure 17*b* is the angles diagram and 17*c* the corresponding additions line. The greatest distance from the transition curve to the base line ABC is

$$e_{max} = \frac{l^2}{108 R} = 0.0092593 \times \frac{l^2}{R} \quad (28)$$

This is found at the distance $\frac{l}{\sqrt{3}}$ from ÜE. *Table 6* gives the distances e for the consecutive tenths of the length l of the transition curve.

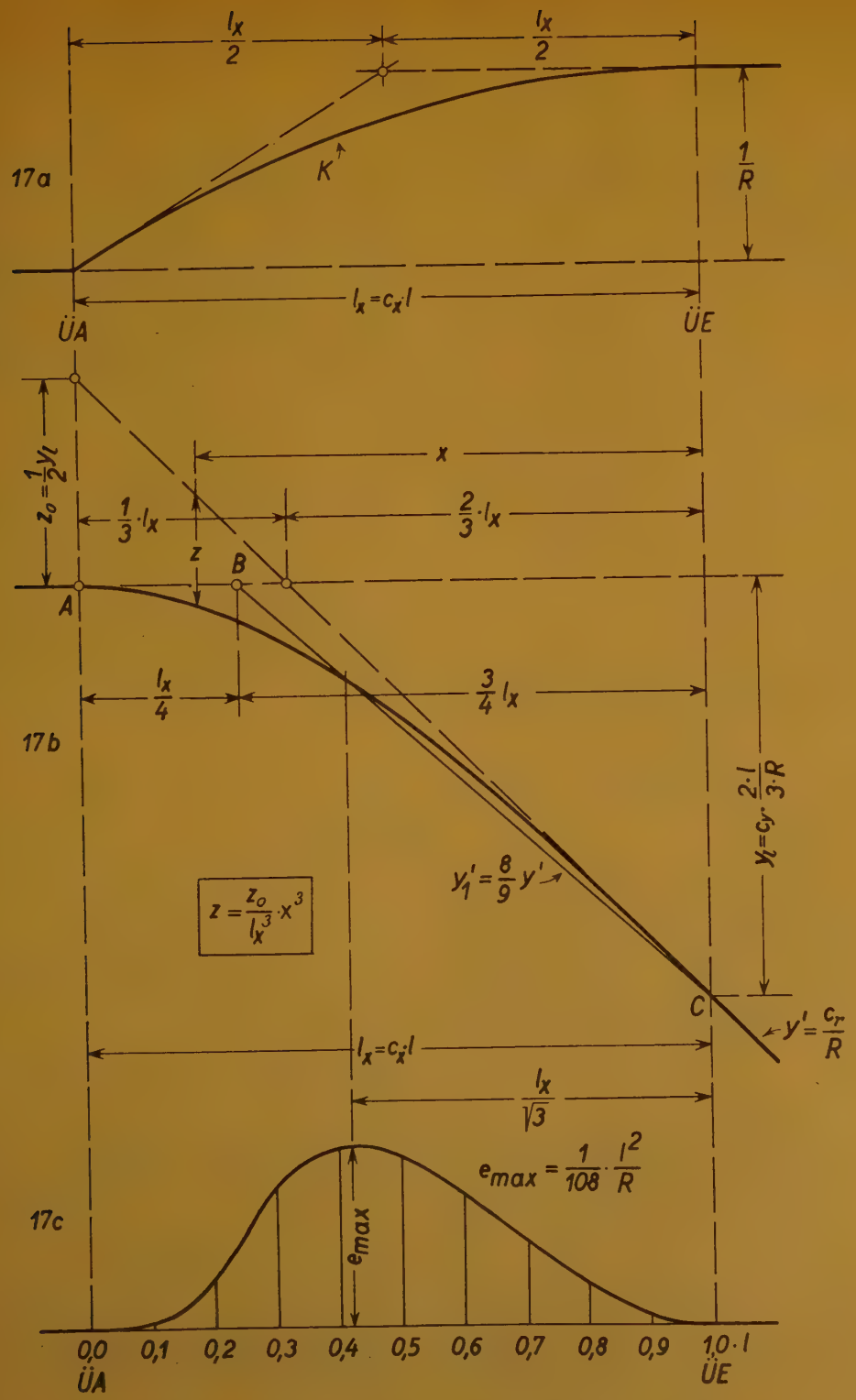


Fig. 17. — Pegging transition curves with parabolic variation.

a) Diagram of curvatures (not drawn to scale). — *b*) Angles diagram. — *c*) Additions diagram (cf. table 6).

Table 6. (Cf. fig. 17c.)

Distance from AÜ	e
ÜA $0.0 \times l$	0
$0.1 \times l$	$0.0003250 \times l^2/R$
$0.2 \times l$	$0.0025333 \times l^2/R$
$0.3 \times l$	$0.0072139 \times l^2/R$
$0.4 \times l$	$0.0092000 \times l^2/R$
$0.4227 \times l$	$0.0092593 \times l^2/R = e_{max}$
$0.5 \times l$	$0.0086806 \times l^2/R$
$0.6 \times l$	$0.0067556 \times l^2/R$
$0.7 \times l$	$0.0043250 \times l^2/R$
$0.8 \times l$	$0.0020889 \times l^2/R$
$0.9 \times l$	$0.0005473 \times l^2/R$
ÜE $1.0 \times l$	0

This layout of the transition curve with parabolic curvature can give good results in the case of curves with small angles at the centre. These curves are sometimes given the form of « *articulated arcs* », that is to say of curves composed of two transitions meeting at ÜE. When the curvature is parabolic (fig. 17*a*) the curvature and the superelevation is perfectly rounded off at the middle of such articulated arcs. An articulated arc has such a curvature when

$$l = \frac{3}{4} \cdot R \cdot \varphi_0 \quad . \quad . \quad . \quad (29)$$

is selected; the intermediate arc of circle between the two transitions then disappears.

When this parabolic curvature is used we can establish, in particular, a transition with perfect continuity, from a curve and superelevation, to the reserve curve and superelevation as shown in fig 18*a* and *b*.

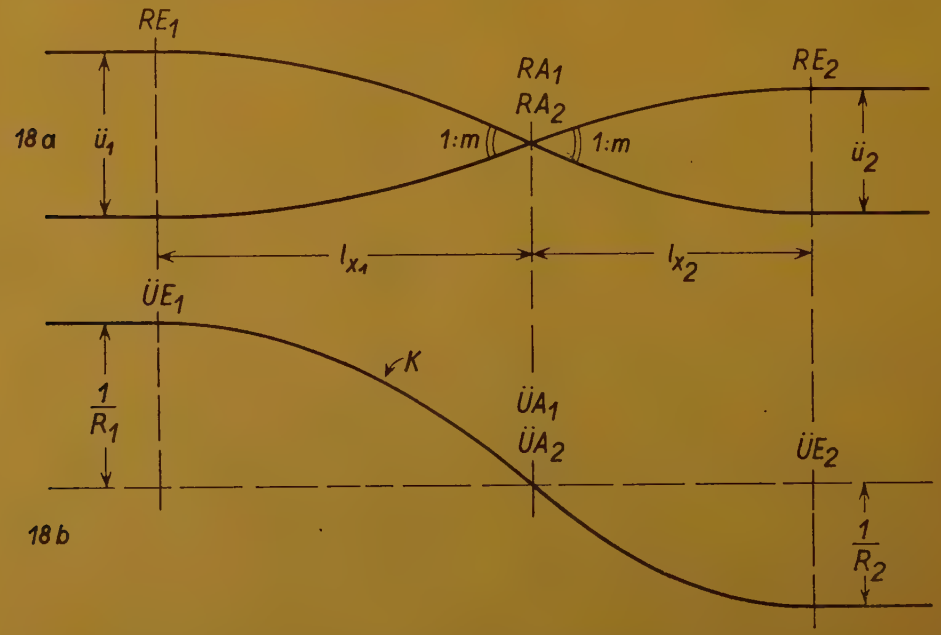


Fig. 18. — Rational layout of reverse curves.

a) Gradients diagram. — *b*) Curvatures diagram (RA = start of the gradient. — RE = end of the gradient. Ü = superelevation, 1 : m = steepest incline on leading in gradient.

17. — Transition curves with parabolic variation of S form.

If we wish the curvature and superelevation to be perfectly continuous in the case of a simple curve (and not a reverse curve) the *parabolic curvature in the form of an S* according to figure 19*a* must be used.

The angles diagram of figure 19*b* corresponds to this line of curvature. It consists of two cubic parabolas AD and DC, which are readily constructed by using the information supplied by figure 19*b*. Transition curves having such curvature can be inserted with advantage in existing railway lines.

When building new lines, transitions of this kind can be pegged as described in §§ **15** and **16**. In this case, we draw a *symmetrical compound curve in three parts* having the radii

$$R_1 = \frac{7}{6} \times R, \quad R, \quad R_1 = \frac{7}{6} \times R.$$

The arcs of circle R_1 must be given the lengths

$$L_1 = \frac{7}{12} \cdot l$$

To ascertain the length t of the tangent (fig. 16*a*) we have the equation

$$t = \frac{7}{6} \times R \times \operatorname{tg} \frac{\varphi_0}{2} \cdot \left[1 - \frac{\sin\left(\frac{\varphi_0}{2} - \frac{l}{2R}\right)}{7 \times \sin \frac{\varphi_0}{2}} \right] \quad (30)$$

To find the origin of the transition we mark off on the tangent from B (fig. 16*a*) the length

$$BA = \frac{5}{12} \cdot l$$

Figure 19*b* shows the angles diagram, and figure 19*c* the corresponding additions line. The greatest distance between the transition and the base line ABC is

$$e_{max} = \frac{l^2}{130.67 \cdot R} = 0.0\,076\,529 \times \frac{l^2}{R} \quad (31)$$

It occurs at the distance $\sqrt{\frac{3}{14}} \cdot l$ from ÜE.

Table 7. (Cf. fig. 19c.)

Distance from ÜA	e
ÜA 0.0 × l	0
0.1 × l	0.0000167 × l^2/R
0.2 × l	0.0002667 × l^2/R
0.3 × l	0.0013500 × l^2/R
0.4 × l	0.0042667 × l^2/R
0.5 × l	0.0074405 × l^2/R
0.5371 × l	0.0076520 × $l^2/R = e_{max}$
0.6 × l	0.0071619 × l^2/R
0.7 × l	0.0050785 × l^2/R
0.8 × l	0.0025905 × l^2/R
0.9 × l	0.0006977 × l^2/R
ÜE 1.0 × l	0

Table 7 gives the distances e for the consecutive tenths of the length l of the transition curve. If, when the angle at the centre is smaller, we wish to give the curve the form of an articulated arc we must choose, with this curvature :

$$l = R \cdot \varphi_0 \quad . \quad . \quad . \quad . \quad (32$$

The methods described in §§ **15** to **17** for pegging long transitions of linear, parabolic and parabolic-S variation when building new railway lines (tables 5 to 7) give acceptable transitions so long as

$$\leqslant 2R \quad . \quad . \quad . \quad . \quad (33$$

(This restriction is due to the equation of condition 20). As in practice, how-

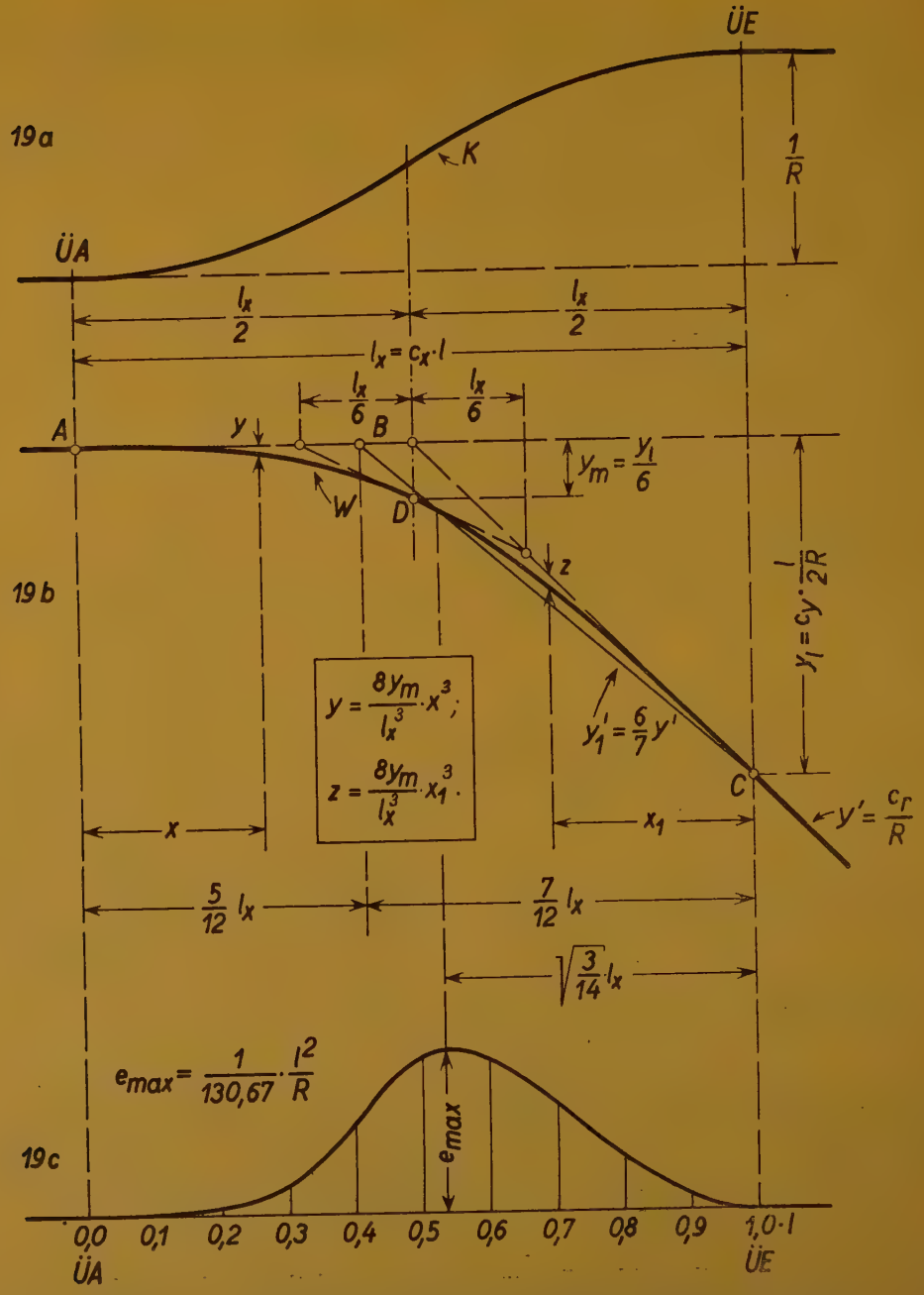


Fig. 19. — Pegging transition curves with parabolic variation of S form.

a) Curvatures diagram (not drawn to scale). — *b*) Angles diagram. — c) Additions diagram (cf. table 7).

ever, transitions of lengths $l > 2$ R are never necessary, these methods are applicable in all cases. They are particularly suitable for laying out *tramway curves*. In such curves, even when the angles at the centre are large, articulated arcs are used when possible. The transition curves then become very long relatively to R. When having to take a right-angle street corner $\left(\varphi_0 = \frac{\pi}{2} = 90^0\right)$ with a minimum radius R = 25 metres, an articulated arc with (equation 33)

$$l = R \cdot \varphi_0 = R \cdot \frac{\pi}{2} = 1.5708 \times R = 39.27\,m.$$

and a curvature of S form is eminently suitable. If quite inadequate transitions were formerly used on tramways, it was solely due to no simple method of pegging transitions with such large angles at the centre being available.

The method of the angles diagram enables us to construct curves of *any variation of curvature*. The general rule, in fact, is that the angles diagram forms the line of the integrals (additions line) for the line of the curvatures $\left(k = \frac{c_3}{r}\right)$ (cf. fig. 5*a*, *b*, 17*a*, *b* and 19*a*, *b*). We can then find by calculation or graphically, for any supposed variation of curvature, the corresponding angles diagram and use this as the base from which to peg the curve as explained in chapters C to E. This problem could not be solved in a general way by the methods formerly available. Equations of transitions, based on a particular system of co-ordinates, are no longer required, with the angles diagram method and are therefore of no interest as it is reasonable to want only a definite curvature for a running line curve, and not an equation.

This means that a curve or pegging can only be *checked* properly *by verifying the curvature directly, that is by measuring the versines.*

PLATE I.

TAFEL 1

km 5,400 450 500 550 600 650 700 750 800 850 840

a) Winkelbild

Auftragslinie

Endparallele

$\frac{\Delta x}{2}$ Δx Δx Δx Δx

$c_h \cdot \sum_{380}^{400} h_k$

$y_{(-)}$

Winkelbild (W)

$\frac{\Delta x}{2}$

$c_h \cdot \sum_{740}^{760} h_k = 6{,}66$ cm

tgß = −1

Endparallele

ÜE $l_x = 13{,}00$ cm ÜA

$\frac{l_x}{2}$ $\frac{l_x}{2}$

D

K

Entwurf (E)

b) Winkelbild und Entwurf

tgß = −1

Endparallele

G

d

Δy $y' = \frac{\Delta y}{\Delta x} = 1{,}412$; $R = 708$ m.

Δx

Richtung der Endparallelen

H

L

Endparallele

tgß = −1

682,9

812,9

398,0

528,0

C

ÜE

ÜA

$\frac{l_x}{2}$ $\frac{l_x}{2}$

$\frac{\Delta x}{2}$

$l_x = 13{,}00$ cm

$= 9 \cdot 14{,}444$ cm

N

T

S

b

Bezugslinie

Auftragslinie

P

$f_{ü} = -0{,}15$ cm

Q

M

$\underline{b}$

Summenlinie (S)

c) Summenbild

+2,57 cm

km 5,400 450 500 550 600 650 700 750 800 850

Maßstab: 0 5 10 15 20 25 30 cm

Explanations of German terms:

Winkelbild = angles diagram. — Entwurf = project. — End parallele = end paralell. — Auftragslinie = plotting line. — Richtung der Endparallelen = direction of end parallels. — Bezugslinie = reference line. — Summenbild = additions diagram. — Summenlinie = additions line. — Massstab = scale.

TAFEL 2

km 5,400 450 500 550 600 650 700 750 800 850

ÜA ÜM ÜE ÜE ÜM ÜA

$\frac{l_x}{2}$ $\frac{l_x}{2}$ $\frac{l_x}{2}$ $\frac{l_x}{2}$

A B C D E F G

$f_{ü} = -0{,}38$ cm

$f = +0{,}60$ cm

$f_{ü} = -0{,}20$ cm

5,00 cm

a) Summenbild

$l_x = 13{,}00$ cm $w = 7{,}745$ cm $w = 7{,}745$ cm $l_x = 13{,}00$ cm

398,0 528,0 682,9 812,9

b) Winkelbild und Entwurf

ÜA ÜE D ÜE ÜA

W E

$y' = 1{,}411$; $R = 709$ m

$d = c_y \cdot \delta$

C S

$\frac{l_x}{2}$ $\frac{l_x}{2}$ $\frac{l_x}{2}$ $\frac{l_x}{2}$

$l_x = 13{,}00$ cm

399,1 529,1 691,7 821,7

c) Summenbild

H K L P

4,00 cm

M N O

$f_{ü} = 0$ $f = -0{,}44$ cm $f_{ü} = +0{,}40$ cm

2,50

Richtung der Bezugslinie

$b' = 1{,}000$

ÜA ÜE ÜE ÜA

$l_x = 13{,}00$ cm $w = 8{,}13$ cm $w = 8{,}13$ cm $l_x = 13{,}00$ cm

km 5,400 450 500 550 600 650 700 750 800 850 900

Maßstab: 0 5 10 15 20 25 30 cm

[621. 134.1]

Locomotive crank axles,

by F. L. BAXTER.

(The Engineer.)

After being out of fashion for some time, crank axles are coming into favour with the appearance of large three- and four-cylinder locomotives. Many engineers, however, still view them with suspicion, and stick to two outside cylinders, even with piston loads in excess of 45 tons, thereby gaining what is really more valuable than a reduction in stresses — only two sets of motion and valve gear to look after. The loading gauge is the deciding factor in a number of countries, a maximum cylinder diameter of only 22 inches being possible in Britain.

Design.

As far ass single-throw cranks are concerned, the solid type with straight webs of elliptical or rectangular shape is used only for piston loads of under 50 000 lb.; otherwise the field is held by the built-up pattern, and by those axles in which the webs are swept up from the axle-box journal to the crank pin in a square or rectangular section, and occasionally in a circular section. This swept-up type is more simple in construction than is its built-up rival, and is also a less costly forging than the plain type with straight webs, but built-up cranks, whether single or double-throw, may, at the designer's discretion, possess the undoubted advantage of being balanced in the plane of the webs, this feature reducing the stress in the axle and keeping down the size of the balance weight in the wheels. It is strange that advantage is not more often taken of this possibility, especially since the type of big-end employed is relatively light, and does not require so much « elbow room » for its dismantling as does the double-bolt strap type.

The built-up principle has not been applied to such an extent in double-throw axles. Two-cylinder locomotives are invariably fitted with the solid type, and many of the latest and largest four-cylinder machines, *e. g.*, the P.-O. and Nord *Pacifics* in France, retain this form, even when, as in the case of the P.-O. locomotive, the pins and webs are balanced in their own plane by extending the crank webs. It is probable that this practice has been retained through the fear of movement in the fits, for the double-throw axle is stressed to a higher degree than is its single-throw counterpart, the equivalent bending stress rising to a maximum of over 12 tons per square inch in large engines. But if the movements of the inside valves be controlled by gear arranged outside the wheels, the Z type of axle may be safely adopted for any piston loads now found with inside cylinders. European engineers favour this system of construction unless they desire inside valve motion, as in the French four-cylinder compounds, but for three and four-cylinder locomotives British and British-built practice favours the built-up pattern. Piston loads, however, rarely exceed 55 000 lb., whereas with the normal solid type they rise to 63 000 lb. with double throws, and in the Z pattern to over 75 000 lb. North American practice provides a contrast to this rule, as with a special type of built-up axle, piston loads up to 126 000 lb. are transmitted.

Unique among crank axles are those

TABLE I. — Crank axle materials.

Railway.	L. and N.E.R.			G.W.R.		L.M.S.R. (M.R.)	Japanese Government Railways.	Norte (Spain).	U.S.A. (various).	U.S.A. (various).
	Axles.	Webs.	Pins.	Axles and pins.	Webs.					Webs.
Type of steel	Carbon.	Carbon.	Carbon.	Carbon.	Carbon.	Carbon.	Vanadium.	Nickel-chrome.	Nickel.	Carbon.
Ultimate strength, tons per square inch	32-38	45-50	42-47	35-40	45-50	28-32	40-42	38-42	37-40	48-50
Yield point, tons per square inch		22.5-25	25-32	20	25	15-17	28-30	28-32	25-29	38-40
Elongation, per cent		15-10	28-24	25-20	16-11	28-38	24-22	20-18	30-28	27-25
Analysis, per cent:										
Carbon			0.25-0.3			0.22-0.25	0.4-0.5	0.2-0.3	0.22-0.26	0.4-0.45
Silicon			0.3 max.			0.16	?	0.25	0.2-0.25	0.25 max.
Manganese	B.S.S.	M	1.4-1.8	M	M	0.7	0.75-0.9	0.4-0.6	0.8-0.95	0.7-0.9
Nickel	No. 8c		M			Nil	Nil	2.0-2.5	2.5-2.75	Nil
Chromium			M			Nil	0.25	0.4-0.6	?	0.85-1.0
Vanadium			Nil			Nil	0.18-0.2	Nil	Nil	Nil
Sulphur, max.		0.05	0.05	0.04	0.05	0.04	0.04	0.04	0.045	0.04
Phosphorus, max.		0.05	0.05	0.04	0.05	0.04	0.04	0.04	0.045	0.04
Remarks		Sum of tensile strength in tons + elongation per cent. to be not less than 60.	Oil-quenched at 850-870° C., and tempered at 640-650° C., « Super-Tough » brand.			Above are typical results. See Fowler, Inst. Loco. Eng., 1924.			Izod value 70-75 ft.-lb.	Oil-quenched at 830° C., tempered at 670° C., Brinell No. 240-250.

fitted to the recent Paris, Lyons and Mediterranean Railway 2-10-2 locomotives. The second and third coupled axles have double throws, the pins of which take *coupling-rods*, set at the usual 90°. Owing to the high power (2 800 H.P.), it was not found possible to get two high and two low-pressure cylinders abreast below the smoke-box, and the high-pressure pair were therefore moved back to the centre of the engine length, and one set of coupling-rods transferred inside to make room for them. The crank pins are set at 15-inch transverse centres, close enough to require only a single web in the centre.

A good example of built-up construction is shown in figures 1 and 2, which illustrate the driving axle of the L. and N.E.R. three-cylinder *Pacifics* and *Moguls*. Five pieces go to make up the axle, the pin and webs being fabricated separately, and the axle portions forged and machined in one billet, as shown in figure 2. An allowance of 1/8 inch on the diameter is left on the wheel seats and axle-box journals, these surfaces being trued up to finished dimensions after the axle forging has been divided, and the webs shrunk on. The webs are bored to the dimensions given in figure 1, the pin and axle portions being turned with a shrinkage allowance of 0.018 inch. After the surfaces have been painted with sal ammoniac, the webs are heated just sufficiently to allow the pin and shaft to go in.

There is evidence of considerable thought having been devoted to the design and construction of these axles, both in dimensions and materials. Axles, webs, and pin are each made of the material calculated to best meet the stresses and service conditions imposed, and as they are of considerable interest, their characteristics are included in table I.

An interesting comparison may be made between the L. and N.E.R. single-throw axle and the double-throw axle of the Great Western Railway, as shown in

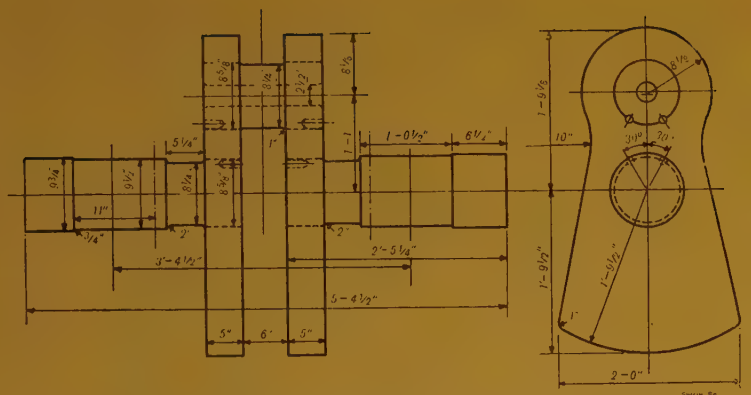


Fig. 1. — Built-up crank axle of L. N. E. R. « Pacifics ».

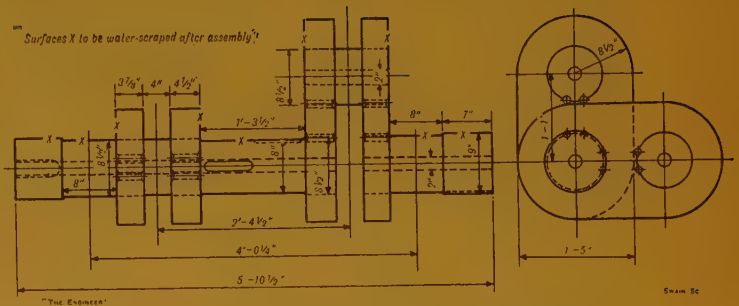


Fig. 3. — Double-throw crank axle, G. W. R.

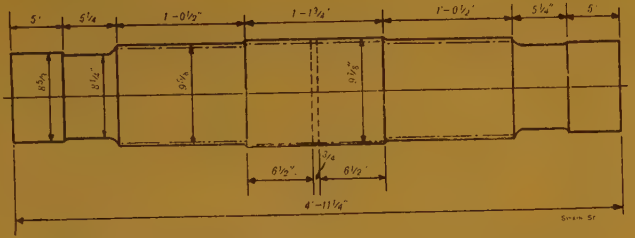


Fig. 2. — Axle portion for L. N. E. R. crank shaft.

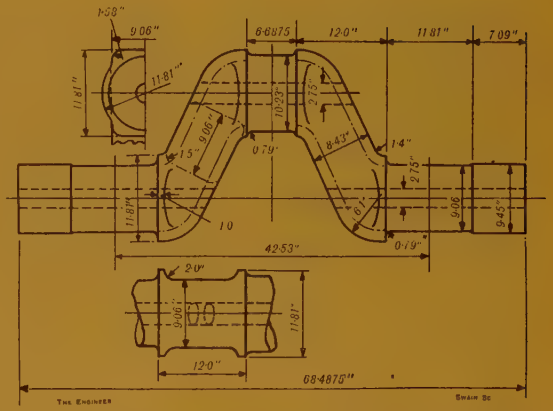


Fig. 4.— Swept-up single-throw axle, Austrian Federal.

figure 3. In this case the webs are not prolonged for balancing, but hollow boring has been carried out through both axle and pin, as against the pin only in the L. and N. E. R. example. It is curious how hollow boring has « caught on » to such a small extent, for, despite a slight extra cost, it reduces the dead weight and centrifugal force, and, if the bore be made large, not only renders the heat treatment more efficacious through equalising the temperature throughout the mass, but also affords a very convenient means of examining the interior of the axle. Especially is this the case in built-up units, where the constituents can be easily handled and inspected before assembly. Of course, once in service, the axle must be examined under more difficult conditions, but this is a good reason for adopting a bore of appreciable size. Boring out to 0.5 of the outside diameter only reduces the strength in torsion and bending by 6 %, while reducing the weight by 25 %.

In the Great Western design the pin and axle fits are not swelled above the journal diameter. The swelling of the centre portion of the axle is effected merely to keep all the holes in the webs the same size, this part having been reduced in diameter for the sake of a slight amount of flexibility, something of this nature being necessary to counteract the stiffening effect of the four excentrics. Another noteworthy point in this design is the large amount of metal in the webs round the pin and axle. Additional security for the webs is provided by two 1 1/4 inch diameter plugs in each fit. The plug holes are tapped right through, and the plugs kept 1/8 inch inside at each end. This may be contrasted with L. and N.E.R. practice, in which two plugs of 1 inch diameter are screwed only half-way through the web, despite a higher piston thrust and axle load.

A somewhat higher shrinkage allowance of 0.02 inch is allowed at Swindon, but neither G.W.R. or L. and N.E.R. allowances approach those which were used on the old Lancashire and Yorkshire Railway, where, with steels of 32-38 tons strength for the webs, and 35-40 tons for the axles and pins, the shrinkage allowed was 1/330 of the nominal hole diameter. That is, where the G.W.R. allow 0.02 inch. for a 8 1/2-inch pin, and the L. N. E. R. 0.018 inch for an 8 1/4-inch pin, the L. and Y.R. allowed 0.0254 inch with steels of lesser strength.

Tolerance allowances observed at Swindon are, in inches :

		Low.	*High.*
Shrinkage fit, axles and pins	Shaft diam.	D + 0.000	D + 0.002
	Hole diam.	D — 0.020	D — 0.017
Distance between webs		L — 0.005	L + 0.005
Journals	Diameter	D — 0.002	D + 0.002
	Length	L — 0.005	L + 0.005
Wheel seat, diameter		D + 0.000	D + 0.002

A massive example of the swept-up type of single-trow axle is that fitted to the Austrian Federal Railways three-cylinder 2-8-4 express locomotive, as illustrated in figure 4. It is made up as a single forging from 5 % nickel steel, with an ultimate strength of 38-40 tons per square inch. In this case the stroke is fairly long, viz., 28.5 inches, so that the sweep is deeper than usual. For economy in material, the crank sweeps in this type of axle are frequently made rectangular, thrust surfaces for the big-ends and axle-boxes being formed at the sides by projections on the sweeps, as shown in figure 4. Hollow boring was almost essential in these Austrian engines, in order to keep down the weight, and all the axles and crank pins were so treated. As this axle was constructed to metric measurements, the equivalent English dimensions are given in decimals to permit of the exact size being recorded.

A departure from normal practice has been considered necessary in North America, owing to the enormous powers transmitted. In the Union Pacific 4-12-2 locomotives, for instance, the piston thrust is 126 000 lb., and the spring load on each journal 23 000 lb. The wheels in the U.S.A. examples are not very large, but it seems probable that the heavy loads will lead to a short life unless exceptional care be taken in the design and construction. The axle incorporated in the New York Central three-cylinder *Mountain* engines is depicted in figure 5. Each fit is of two diameters, and this necessitates skilful handling during the shrinking operations; but it ensures that no lateral movement can take place between the webs and the pin or axle, while a key on the smaller diameter of each fit prevents rotational movement.

Lubrication of the pin is effected by hard grease, forced down the hollow boring in the left-hand portion of the axle. In neither pin nor axle portions does the hollow boring extend right through, and in the pin the bore is closed up entirely by a screwed plug, which is welded over. Apparently, the experience with these New York Central axles — which, incidentally, weigh a shade over 3 tons — led to increased confidence as to their probable life, for the more recent Union Pacific 4-12-2 machines have the same type of axle with practically no increase in scantlings — see table III — although the piston load is higher by over 25 %. There are now over eighty of these axles in service in 4-12-2 locomotives, the material being nickel steel.

Materials.

It is by no means certain what constitutes the best material for crank axles. The British Standard Specification calls for a minimum ultimate tensile strength of 32 tons per square inch in conjunction with a minimum elongation of 22 % on 2 inches. Very many railways keep closely to the terms of this specification, which do not cover analysis, but the old Midland Railway found that a ductile steel, with a strength of only 28 to 32 tons per square inch, and a maximum carbon content of 0.25 %, gave the longest life. In fact, the Midland engineers went down the ultimate strength scale as far as possible without leading to a short life through wear on the pins and journals.

At the other end of the scale are alloy steels with strengths of 37 to 40 tons, and occasionally above the latter figure, which are characterised by extreme toughness and shock-resisting capacity. Such materials are not confined alone to built-up shafts, but have been extensively used during recent years for single and double-throw axles. The most popular type is a nickel-chrome alloy containing 2 to 3 % of nickel, and 0.4 to 0.6 % of chromium. A number of European railways specify a nickel content of 5 %, and in one case a maximum of 7 %, but the Norwegian State Railways, which formerly tolerated up to 5 %, now call for a maximum of 3 %. As used on the Bulgarian and Rumanian State Railways, 5 % nickel steels are required to give a tensile strength of 38-40 tons per square inch, and a minimum elongation of 18 % on 8 inches, and these may be taken as representative figures for the general run of alloy steels.

A selection of materials used by different railways is given in table I. Although the Great Western Railway leaves the analysis entirely to the manufacturer, except that the maximum sulphur and phosphorus contents are stipulated, the specifications as to mechanical properties and resistance to stress repetition are very complete, and a suitable material is thus ensured. There is much to be said for specifications drawn up in this manner, recognising, as they do, the undoubted experience of the manufacturer. The sum of the ultimate strength

TABLE II. — Particulars of double-thr

Railway	G.W.R.	G.W.R.	L. & N.E.R.	Southern	East Indian	G.I.P.
Wheel arrangement . .	0-6-0T	0-6-2T	4-4-0	4-6-0	0-6-0	2-10-0
Class	57 XX	66 XX	Director	Lord Nelson	1375-1389	N/I
A (fig. 6) . . . inches	12.0	13.0	13.0	13.0	13.0	13.0
B . . . . . »	27.0	28.5	24.5	23.0	32.0	27.0
C . . . . . »	47.0	48.25	46.5	46.0	55.0	52.0
D . . . . . »	6.75	8.0	7.75	9.0	7.75	?
E . . . . . »	7.5	8.5	8.0	9.0	8.0	8.5
F . . . . . »	8.0	8.0	9.0	10.5	9.0	11.0
G . . . . . »	8.0	8.5	8.5	9.0	8.5	8.5
H . . . . . »	4.0	4.0	4.5	4.5	4.5	4.5
J . . . . . »	4.25	4.5	4.5	4.25	4.75[2]	Nil
K . . . . . »	4.0	3.875	4.25	4.0	4.75[2]	4.75
L . . . . . lb.	15 000	16 400	17 000	17 000	15 700	15 800
P . . . . . »	48 150	50 800	56 500	47 050	50 266	50 266
Method of construction .	Built-up	Built-up	Solid	Built-up	Solid	Solid Z
Type of web (fig. 7) . .	1	1	2	4	3	?
Wheel diameter . inches	55.5	55.5	81.0	79.0	61.5	56.5

(1) Unhooped. (2) Hooped. (3) Balance weights bolted on.

TABLE III. — Particulars of single-thr

Railway	L. & N.E.R.	L.M. & S.R.	Czecho-slovakian State	Austrian Federal	German State
Wheel arrangement . .	4-6-2 & 2-6-0	4-6-0	4-6-2	2-8-4	2-8-2
Class	A 1 & K 3	Royal Scot	387.001	114	P. 39
A (fig. 6) . . . inches	13.0	13.0	13.39	14.17	13.0
C . . . . . »	40.5	43.5	43.31	42.53	47.25
D[1] . . . . . »	8.25	8.5	8.65	—	—
E . . . . . »	9.5	9.0	8.65	9.06	9.45
F . . . . . »	11.0	10.5	10.23	11.81	10.23
G . . . . . »	8.25	8.5	9.45	10.23	9.84
H . . . . . »	6.0	5.5	6.296	6.6875	6.6875
J . . . . . »	5.0	5.0	5.0	8.43×9.06	9.45[2]
K . . . . . »	5.0	5.0	5.0	—	—
L . . . . . lb.	15 700	16 800	14 500	15 000	14 300
P . . . . . »	56 500	63 700	62 100	73 100	66 000
Method of construction .	Built-up	Built-up	Built-up	Solid swept	Solid swept
Type of web (fig. 7) . .	4	4	4	—	—
Wheel diameter . inches	80.0 68.0	81.0	76.76	76.375	69.0

(1) Portion between journal and web. (2) Square. (3) Hollow bore of 3 in.

x axles (see figs. 6 and 7).

ether-lands	Norte (Spain)	Nord (France)	Est (France)	P.-O. (France)	P.L.M. (France)	P.L.M. (France)	German State
4-6-0	4-8-2	4-6-2 Super-	4-8-2	4-6-2	4-8-2	4-8-2	4-6-0
3900	3601	Pacific	241-002	3701	241.A	241.C	S.10
3.0	13.375	13.578	14.17	12.8	12.8	12.8	12.4
3.0	29.125	26.0	25.0	26.78	21.656	19.29	20.1
5.7	55.56	48.22	48.03	47.9	46.06	46.06	44.1
9.45	9.062	7.87	9.45	8.65	?	?	7.88 × 11.02
8.875	9.062	8.078	8.65	8.65	8.65	8.65	8.65
8.875	10.25	9.25	8.65	9.54	9.06	9.86	10.25
9.6875	9.875	8.27	8.86	9.06	8.86	9.45	9.06[4]
4.328	5.65	5.515	5.32	5.12	7.484	7.484	4.57
4.92	4.53	5.515[1]	4.5	4.14	Nil	Nil	Nil
4.76	4.53	3.73[2]	4.5	4.14	3.94	4.718	4.34
16 000	12 500	15 000	13 600	15 000	14 000	15 000	14 500
43 000	57 500	54 500	46 500	47 000	73 500	71 500	46 000
Solid	Solid	Solid 1 inner	Solid	Solid	Built-up Z[5]	Built-up Z[5]	Solid Z
2	2	2 outer	4[3]	4	3	3	3
73.0	69.0	74-75	76.75	76.75	70.5	78.75	78.0

([4]) Hollow bore, 2.36 inches diameter. ([5]) Balanced.

k axles (see figs. 6 and 7).

erman State	Danish State	Est (France)	Norte (Spain)	B.A.P.R.	B.A.G. S.R.	N.Y.C. R.R.	U.P.R.R.
4-6-2	4-6-0	2-10-0	4-8-0	4-6-2	2-6-4-T	4-8-2	4-12-2
oeffler super-	955	150-141	B. & W.	2 101	3 530	Alco	9 000
ressure							
13.0	13.2	13.0	13.0	13.0	13.0	14.0	15.5
39.375	43.3	43.375	51.67	53.0	52.0	41.25	41.0
—	—	—	—	8.0	9.0	11.25	11.75
9.45[6]	8.26	8.86	8.26	9.0	9.0	11.5[3]	12.0
11.81	10.23	10.23	10.23	10.0	10.0	13.75	13.0
10.23[6]	9.06	9.45	9.06	8.5	9.0	12.0[4]	12.5
7.48	6.6875	6.6875	5.516	5.0	5.5	7.5	8.0
9.45[2]	9.06[2]	?	10.62[5]	4.75	4.5	9.0	8.5
—	—	—	—	4.75	4.5	9.0	8.5
17 000	14 600	15 000	12 700	15 500	15 700	24 500	23 000
93 500	45 800	76 000	61 200	48 320	48 100	98 000	126 000
Solid swept	Solid swept	Solid swept	Solid swept	Built-up	Solid	Built-up	Built-up
—	—	—	—	4	3	See fig. 5	See fig. 5
78.75	73.5	55.2	61.5	71.0	68.0	69.0	67.0

([4]) Hollow bore of 3 3/8 in. ([5]) Diameter. ([6]) Hollow bore of 2 3/4 in.

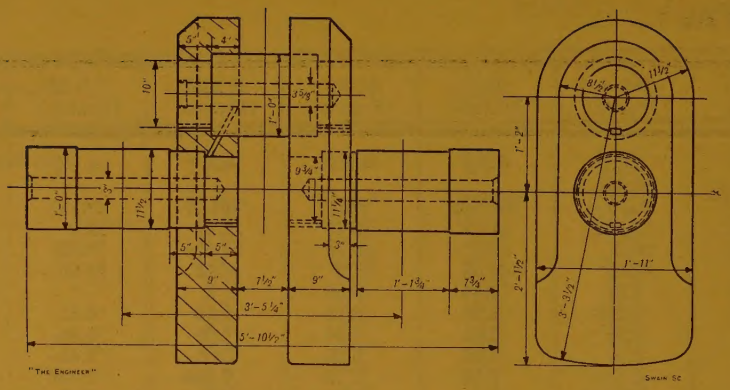


Fig. 5. — Crank axle of New York Central « Mountain » locomotives.

in tons and the elongation in per cent, of the Great Western web material, must not be less than 61, while the bend test specified consists of bending a 1 1/4-inch square bar, 9 inches long, round 2 1/2 inches diameter until the ends are parallel. In the revolving fatigue test a piece 3 inches long and 1/2 inch in diameter has a waist turned down in the centre to a diameter of 0.399 inch over a width of 0.375 inch. A weight is hung from the waist at a radius of 7 inches, and with the resulting fibre stress of 27 tons per square inch the test piece must withstand

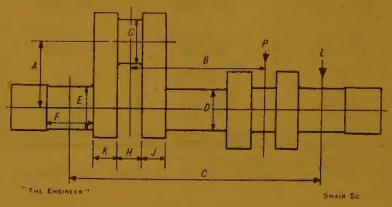


Fig. 6.

20 000 revolutions. This material is normalised only, but the axle and pin steel is oil-treated, although it does not under-

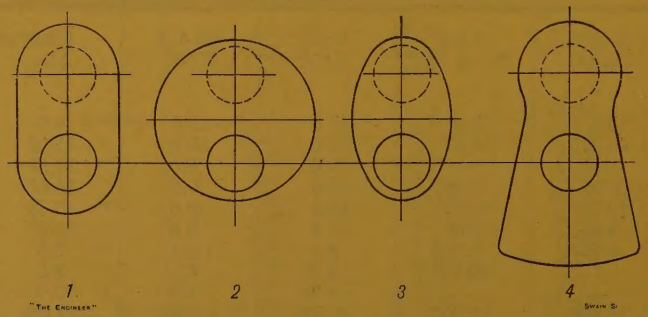


Fig. 7.

go a fatigue test. It is worth noting that the specified elongation is taken over a different length than is stipulated for the web material.

Both the L. and N.E.R. and G.W.R. prefer a carbon steel, although the specification leaves the way open for the inclusion of small quantities of nickel or

chromium, but in each case the webs are of one of the « Super-Tough » brands of carbon steel. It will be noted, however, that while the ultimate strength is above that of alloy steel, the yield point and elongation are decidedly inferior to the values obtained with even the simplest alloy steels.

The large carbon content of vanadium steels, as used in Japan and America, compared with what is found in nickel brands, is desirable on account of the remarkable affinity of vanadium for that element. Nickel, on the other hand, does not depend upon the presence of carbon for its characteristics, as it is entirely absorbed by the iron constituent of the steel. Nickel is introduced as an alloying element in order to gain toughness and strength, but it also hardens the steel to some extent, giving good wearing properties without an appreciable increase in brittleness. Chromium, in contents up to 0.7 %, acts as a purifier, and produces fineness of grain with even microstructure. Its advantages are now so clearly recognised that plain nickel steel is almost obsolete where high impact values are desired. The low tensile strength and simple heat treatment, compared with those found in connecting-rod steels, has made the adoption of molybdenum-bearing steel unnecessary, but if a tensile strength higher than those now found in crank axles should, in the future, become desirable, the necessary shock-resisting capacity will only be obtained by the inclusion of 0.3 to 0.6 % of molybdenum. Nickel steels are very liable to take on temper brittleness during cooling, but this is obviated by the introduction of molybdenum, which thus adds hardness and strength, in addition to throwing scale during forging operations. In nickel or nickel-chrome steels of the type now used for crank axles, molybdenum is usually tolerated as an impurity in contents not exceeding 0.25 %.

Vanadium steel can claim to be the simplest of alloy steels, and can be forged and machined as easily as normal carbon steel. From a railway point of view its chief merits are that neither quenching nor tempering are required — a simple normalising and annealing being all that is necessary — and local heating for repairs has no adverse effect upon the material, this property being in striking contrast to the behaviour of nickel-chrome steels. Vanadium steels usually contain over 0.8 % of manganese, and as both elements oxidise very easily they have a powerful scavenging effect. Adjustment of the tensile strength is carried out by varying the proportion of manganese, the vanadium content varying only between the narrow limits of 0.16 to 0.22 %.

Proportions.

In tables II and III are presented the dimensions and relevant particulars of a selection of modern double and single-throw crank axles. Examination of the values relating to the two P.L.M. 4-8-2 classes shows that, for almost similar piston and main bearing loads, the larger-wheeled example has the greater scantlings. While the closer spacing of the inside high-pressure cylinders renders this possible without any difficulty, it would in any case be desirable, as crank axles carrying large wheels have shorter lifes than those with small wheels. Figures for the life of both types, as obtained on the old Lancashire and Yorkshire Railway, were given by Shawcross in the *Proceedings*, Inst. Loco. Engrs., 1926.

The web thickness averages 0.5 of the crank pin diameter in double-throw shafts, and slightly more in single-throws. Average values for stresses and bearing pressures of various types of crank axles were given in *The Engineer* for June 17th, 1932.